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QUARTERLY PROGRESS REPORT

Twelfth Force Declassification Office
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Date 4-30-84 Reviewer BZ

DIVISION 6 — DIGITAL COMPUTER (U)

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15 SEPTEMBER 1956

LINCOLN LABORATORY

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DEPARTMENT OF THE AIR FORCE
HEADQUARTERS ELECTRONIC SYSTEMS DIVISION (AFSC)
HANSCOM AIR FORCE BASE, MASSACHUSETTS 01731

41713

REPLY TO ATTN OF: ALFL (Lincoln Laboratory) 17 Dec 84

SUBJECT: Declassification of Lincoln Laboratory Documents

TO: Mr. M. Wesley/A-109
Security Office
Lincoln Laboratory

1. Reference your letter of 17 Nov 1983 requesting declaassification and public release of MIT Lincoln Laboratory Quarterly Progress Reports issued between June 1952 and December 1958 (see atch 1).

The first major hurdle of this process has been cleared. Attachment 2 authorizes the declassification of the following documents:

"Quarterly Progress Reports - Division 6 - Digital Computer"

15 Jun 1954 (C) (LL # 1, C315172C)
15 Sep 1954 (C) (LL # 1, C315189C)
15 Sep 1956 (C) (LL # 1, C315208C) 41713
15 Mar 1957 (C) (LL # 1, C315206C)
15 Jun 1957 (C) (LL # 1, C315253C)
15 Sep 1957 (C) (LL # 1, C315254C)
15 Dec 1957 (C) (LL # 1, C315255C)
15 Mar 1958 (C) (LL # 1, C315256C)
15 Jun 1958 (C) (LL # 1, C315257C)
15 Sep 1958 (C) (LL # 1, C315258C)
15 Dec 1958 (C) (LL # 1, C315313C)

The next major hurdle is obtaining public release. This will be done through ESD Public Affairs (Mr. John O'Brien).

ORIGINAL SIGNED BY

THOMAS J. ALPERT, Major, USAF
Chief, ESD Lincoln Laboratory Project Ofc

2 Atch
1. Lincoln Laboratory Ltr, 17 Nov 1983
2. NORAD Ltr, 26 Nov 84

Cy to: D. Murphy/B-107 w/atch
W. Hill/L-339 w/atch

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NORTH AMERICAN AEROSPACE DEFENSE COMMAND
PETERSON AIR FORCE BASE, COLORADO 80914-5001

REPLY TO ATTN OF J30S

26 NOV 1984

SUBJECT Classification Review "Quarterly Progress Reports"

TO ALFL (Lincoln Laboratory)

1. In response to ALFL letter, 28 Nov 83, the (11) confidential documents titled "Quarterly Progress Reports - Division 6 - Digital Computer" and dated 15 Jun 1954 through 15 Dec 1958 have been reviewed. Recommend the documents be declassified in whole since the sage system computer no longer exists and information contained in the documents no longer has an effect on national security.

2. To officially declassify these, documents, the 416L Security Classification Guide OPR, which is at HQ Sacramento Air Logistics Center, McClellan AFB, CA (MMCM), must be contacted with the recommendation to declassify.

JOHN E. MOORS, LCOL, CF
Ch, At Sensors Division

Memo for Record 14 Dec 84

Talked, by phone, with Ed Smalden, Sacramento ALC/MMCM, McClellan AFB, CA. Based on the recommendation in this letter he considers these documents declassified.

THOMAS J. ALPERT, MAJOR, USAF
CHIEF, ESD LINCOLN LABORATORY PROJECT OFC

Atch 2

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QUARTERLY PROGRESS REPORT

DIVISION 6 – DIGITAL COMPUTER (U)

15 SEPTEMBER 1956

(Issued 26 APRIL 1957)

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LINCOLN LABORATORY LEXINGTON, MASSACHUSETTS

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DIVISION 6 SUMMARY

Division 6, during June, July, and August, 1956, conducted Experimental SAGE Subsector (ESS) subsystem tests using the SAGE prototype (XD-1) and the Cape Cod System (WWI) computers; continued detailed planning of ESS shakedown testing to start in December 1956; continued preparation and checkout of AN/FSQ-7 computer programs and their adaptation to ESS; made specific plans to staff the first three production subsectors with computer programmers capable of adapting, installing, and checking out the air defense computer programs at these sites; organized with RAND a training program for RAND personnel who will install the computer programs at SAGE centers subsequent to the first three; proceeded with the expansion of the Lincoln experimental computer (TX-0) from an 18-bit to a full 36-bit word length machine designated as TX-2; and participated in ADC weapons employment meetings concerned with the integration of new weapons with SAGE.

Live aircraft were successfully tracked during ESS height-finder subsystems tests. The data was encouraging and corroborated results of height-finder accuracy tests run last winter.

Detailed plans are being made for shakedown testing of the Experimental SAGE Subsector based on the General Test Plan written in the previous quarter. Schedules are being adjusted to correspond with the new dates for completion of the direction center computer program. Best estimates are that ESS shakedown testing will begin no later than December of this year.

The RAND Corporation has intensified its recruiting campaign to hire some 400 people whom Lincoln will train to adapt, install, and check out the air defense computer programs at SAGE centers across the country. The computer programs at the first three centers, McGuire, Stewart, and Syracuse, will be installed under the direct supervision of Group 66 Lincoln and RAND personnel. These first three installations will provide on-the-job training for the RAND people and also provide them with valuable background experience for carrying on the installations at subsequent centers.

The computer program for the active computer of a SAGE direction center (the DCA program) has been divided into two major parts, or "packages": air surveillance and weapons direction. The air surveillance package is expected to be coded, parameter checked, assembly tested, and adapted to the Experimental SAGE Subsector in time for Group 64's ESS shakedown testing which is scheduled to begin early in December. At the end of this quarter, coding and parameter checkout were about 87 per cent complete on this package which includes the computer programs for radar inputs, manual track detection and initiation, automatic tracking, track data simulation, and recording.

TX-0, an experimental 18-bit computer, is being expanded to a full 36-bit word length machine which has been designated as TX-2. TX-2 will use the 256 × 256 × 38 (2.5 million bit) memory, plus a completely transistorized 64 × 64 × 37 memory which uses the new

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50-30 mil cores. Both memories have extra bits for parity checking. Improved and more extensive transistor circuitry will be incorporated in TX-2. Since the design of TX-2 permits the concurrent operation of several input and output devices, it is essentially a number of logically separate computers which use the same memory, program, and arithmetic element. Its 36-bit registers can be addressed directly by all instructions, as well as by load and store instructions, thereby retaining much of the flexibility of a double-address code without sacrificing the simplicity of a single-address code.

Twenty of the 38 planes of the $256 \times 256 \times 38$ memory for TX-0 and TX-2 were assembled in the memory stack and adjustments were nearly completed at the end of the quarter. This stack of 20 planes is expected to be operating in September.

The integration of SAGE with the F89H and F89J, F102A, F104A, BOMARC IM-99, Talos IM-70, and Army antiaircraft weapons is being studied. Lincoln Laboratory has participated in five ADC meetings held to discuss the employment of these weapons.

R.R. Everett
Division Head

N.H. Taylor
Associate Division Head

S.H. Dodd
Assistant Division Head

J.F. Jacobs
Assistant Division Head

1 April 1957

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GROUP SUMMARIES

GROUP 61 – SAGE OPERATIONAL PLANNING

The operational and mathematical specifications which define the air defense functions of a SAGE direction center are being refined to eliminate the inconsistencies and ambiguities that are revealed during the writing of the computer program. The specifications covering emergency capability and test-message sequences have been temporarily set aside in order to complete more pressing work.

The mathematical specifications for the simulated data generation programs for the Memory Test Computer are in preparation, and programming is already under way. A review of the requirements for ESS data reduction has been made, and programming has started. Responsibility for these activities has been transferred to Group 64.

The master specification for adapting the operational and mathematical specifications to SAGE direction centers has been drafted. The adaptation activity is now the responsibility of Group 67.

Satisfactory progress has been made on the preparation of operational specifications for the SAGE combat centers. Completion of both operational and mathematical specifications is scheduled for January 1957. The entire combat center activity has been transferred to Group 66.

New weapons systems are being studied with respect to their integration with SAGE. Representatives of Group 61 have attended and participated in five ADC meetings which were held to discuss employment of the F89H and F89J, F102A, F104A, BOMARC IM-99, Talos IM-70, and Army antiaircraft weapons in the SAGE system of air defense. The SAGE/F102A/MG-10 study, conducted jointly with Convair and Hughes, was concluded and a draft report was circulated to people concerned for their comments and recommendations. A SAGE-Talos IM-70 integration study was completed at the end of the quarter and a report is being written.

D.R. Israel

GROUP 62 – ESS INSTALLATION

BTL test specifications were used for the first time in subsystem testing during this quarter. The height-finder subsystem using XD-1, has successfully tracked a live aircraft. Encouraging data was obtained from height-finder accuracy tests performed between South Truro and Whirlwind I, corroborating data obtained earlier in the year. The unavailability of computer time has hampered subsystem testing and necessitated rescheduling to insure that the testing essential to ESS shakedown tests will be completed by the time the particular subsystem is needed.

Two groups of engineers are working on the long-term problems of system checkout techniques. One group is studying the problem and writing computer programs which will expedite such checkouts; the other group will coordinate maintenance activities and perform the system checkouts as the techniques are debugged.

Arrangements have been made between IBM, Lincoln, and the Air Force to permit and finance, on short notice, small changes to ESS equipment. This arrangement should materially expedite equipment testing and acceptance.

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The Bendix LRI monitor consoles arrived during the quarter. Some design deficiencies in them were discovered during testing and Bendix is working to clear up the troubles.

Testing of the commercial hardware to be used in the XD-1 centralized probe system has been completed and installation of the system is expected to begin during the next quarter.

J.A. O'Brien

GROUP 63 – ADVANCE DEVELOPMENT

TX-0, an experimental, 18-bit, digital computer is being expanded to a full 36-bit machine designated as TX-2. TX-2 will have the use of the 256 × 256 × 38 (2.5 million bit) memory, plus the completely transistorized 64 × 64 × 37 memory which uses the new 50-30 mil cores. Improved and more extensive transistor circuitry and packaging, over that of TX-0, will be incorporated in TX-2. The design of TX-2 permits the concurrent operation of several input and output devices, making it essentially a number of logically separate computers which use the same memory, program, and arithmetic elements. Although TX-2 is a single-address system, its 36-bit registers in the arithmetic, exchange, and control elements can be addressed directly by all instructions as well as indirectly by load and store instructions, thereby retaining much of the flexibility of a double-address code without sacrificing the simplicity of a single-address code.

Twenty of the 38 planes of the 256 × 256 × 38 memory for TX-0 had been assembled in the memory stack by the end of the quarter. Adjustments are nearly completed and the stack of 20 planes is expected to be operating early in September.

A tape-drive system has been designed for TX-2 which is expected to eliminate the mechanical complications and, therefore, much of the extensive maintenance required by most commercially available computer tape drives. The design will allow reading over a wide range of tape speeds.

Sample 4 × 4 memory planes were constructed using printed circuits to link the cores together instead of the conventional wiring. Several methods of printing the circuits are being evaluated.

Thin films of 80-20 Permalloy have been vacuum-evaporated and preparations are being made to develop circuits that will use thin films of magnetic materials as memory (information-storage) elements in digital computers.

A study of the switching characteristics of Philco surface-barrier transistors has been completed. The study disclosed that several independent, relatively easy to measure, sets of parameters may be used to specify the switching transistor, instead of the difficult measurements of forward and inverse cutoff frequencies.

A new, micro-alloy transistor, type L-5134, developed by Philco, is in pilot-line production. Driving circuits which must supply high currents are already being designed to use the L-5134 because of its high grounded-emitter current gain.

Transistor life tests through August show a failure rate of 0.06% per 1000 hours of operation.

D.R. Brown
C.L. Corderman
W.N. Papian

GROUP 64 – ESS SHAKEDOWN TESTING AND MTC, WWI OPERATION

The general plan for system shakedown testing of the Experimental SAGE Subsector (ESS) has been expanded to provide more details on (1) operator requirements, (2) operating procedures at sites external to the direction center, (3) data reduction, (4) photographic recording, (5) test specifications, and (6) test schedules. The memorandums covering these areas of test planning supplement the General Test Plan, 6M-4325 (draft), and have been published for review and comment.

Reliability of the Memory Test Computer is being improved for the support of ESS and CCS (Cape Cod System) tests. The magnetic-tape system is being used full time but efforts to improve its operation continue. Specifications have been written for the purchase of two new power supplies with larger capacities than those now used. A closed-circuit TV loop is being investigated as a possible computer input.

WWI will be expanded as part of the large-scale increase in the Cape Cod System. WWI core memory will be increased from 2048 to 6144 registers. A semiautomatic height-finder request facility and equipment for accepting LRI data from Bath, Maine, will be added. Some consoles in the Cape Cod direction center will be relocated to accommodate the additional equipment. The work is expected to be completed about mid-November and, to date, is on schedule.

E.S. Rich

GROUP 65 – VACUUM TUBES

Stromberg-Carlson produced 209 acceptable Charactrons this quarter at a production efficiency of 76%. This was greater than the demand at Hazeltine. Life tests on early production Charactrons were continued at Stromberg-Carlson and MIT. Considerable operational history of the Charactrons, produced prior to the fall of 1955, has been obtained from the display consoles in which seventy Charactrons had accumulated an average of 2067.2 hours as of 21 August 1956. The chief cause for failures in all of the tubes in the life-test programs continues to be low cathode emission.

Several different processing specifications have yielded bariated-nickel cathodes giving 4000-5000 hours of operation. Although there have been variations within groups, a sufficient number of successful cathodes have been processed to warrant continued development of final processing specifications.

Seventeen early production Typotrons on the MIT life rack have accumulated an average life of 7329.4 hours on 31 August 1956. Ninety-three Typotrons in the display consoles have accumulated an average of 2642.5 hours.

General Electric has submitted to Wright Field a proposed MIL specification for the low-power twin triode 6414. They have been experiencing some production difficulties with microphonics which might be associated with their P50 alloy cathode sleeve. Raytheon has started full-scale production of this tube as second source. Their first production lots lacked uniformity and did not show good centering of tube characteristics.

Sylvania has terminated the pilot production of the dual-control gate pentode, type 6888, and turned over the production to their Brookville plant. Bendix is producing the 6888 as second source but experiencing high shrinkage in their first production lots.

The IBM-sponsored development program at Tung-Sol failed to yield an improved version of the 5998. Tung-Sol will continue the program with their own funds. Both Tung-Sol and Chatham are producing the 5998 for the AN/FSQ-7.

P. Youtz

GROUP 66 – SAGE DC AND CC SITES

The responsibility for adapting, installing, and checking out the air defense computer programs at the first three SAGE sites was assigned to Group 66 early in the quarter. In the course of making the McGuire, Stewart, and Syracuse centers operational, Group 66 will train the people necessary to make the remaining sectors and subsectors in the SAGE System operational. As a first step, a study was made of the schedules set up for the availability of the program for the active computer of a direction center (the DCA program); and a schedule of the work at the sites, together with the assumptions upon which the schedule was based, was published as 6M-4397, "SAGE On-Site Air Defense Program Checkout Schedule." The manpower that will be required to accomplish program installation was estimated on the basis of 6M-4397; approximately 30 new staff people per month will be needed until a total of 400 has been employed. The RAND Corporation has contracted to perform the program installation at the sites subsequent to the first three and has initiated an intensive recruiting campaign to hire the people required. Since these new people will be primarily inexperienced, a training program was established for them by Group 66.

Best estimates indicate that a total of ten teams, composed of about forty staff people each, will be required. Each team will be divided into three sections covering the following related but definitive activities:

(1) a. Computer operations
    b. Installation and checkout of the utility system
(2) Installation and checkout of the air surveillance portion of the DCA computer program
(3) Installation and checkout of the weapons direction portion of the DCA computer program.

Responsibility for the Equipment Program Services Committee (EPSCOM), which wrote computer programs for testing subsector equipment, was taken over by Bell Telephone Laboratories during the first part of the quarter. The EPSCOM organization within Group 66 was dissolved during the second week of July.

Responsibility for the Division 6 Production Coordination Office (PCO) was transferred to the Lincoln PCO in Division 2 early in the quarter. Some problems of a PCO nature remained and are being handled by one man in Group 60. The people who had been working in this activity were reassigned within Group 66.

B.E. Morriss

GROUP 67 – PROGRAM PRODUCTION

To eliminate further delay in the shakedown testing activities of Group 64 as a result of the slippage in the programming schedule, reported in the previous Quarterly Progress Report, the computer program for the active computer of a SAGE direction center (the DCA program) has been broken down into two major parts: air surveillance and weapons direction. The group of programs which make up the air surveillance "package" are expected to be coded, parameter checked, assembly tested, and adapted to the Experimental SAGE Subsector (ESS) in time for Group 64's activities, which are scheduled to start about the first of December. At the end of the quarter, the coding and parameter checkout of this package was about 87 per cent complete.

Test procedures have been established, input simulation programs have been written, and the recording and processing programs for test outputs have been provided for the assembly testing of the DCA program. All 22 programs of the air surveillance package were coded, and testing had been completed on the 6 programs of the radar-inputs function.

Coding was completed for adapting the 22 programs of the air surveillance package to ESS. About 3000 registers of information are involved in the adaptation parameters.

Differences between the AN/FSQ-7 computer and its prototype, the XD-1, and the manner in which the differences will affect the computer programs have been determined; the necessary modifications to the programs are being made. The specifications required to bring the console keyboard input switches for XD-1 and AN/FSQ-7 into agreement with the latest version of the operational specifications have been issued. A check of the operational specifications against the computer program continues so that discrepancies between them may be eliminated.

J.A. Arnow
H.D. Benington
C. Zraket

GROUP 60 – ADMINISTRATION AND SERVICES

Electronic construction, mechanical design, component analyses, and model shop services are provided by Group 60 for special Division 6 jobs. Drafting, editorial, reproduction, and distribution services are also provided for Division 6 memorandums and reports. Allocation of Division space and administration of Division personnel is also the responsibility of this group.

The feasibility of single-knob control of marginal checking voltages has been demonstrated by a prototype power supply. This appears to solve the problem of accurately varying marginal checking voltages between limits of –150 volts and +150 volts with minimum chance for error. An order for three of the new designs has been placed.

The size of the Memory Test Computer input mixer plug-in unit has been greatly reduced and, at the same time, made more versatile by the design of a molded plastic package based on the use of Amphenol ribbon connectors and American Marine Products taper-pin holders. The mixer package was designed for quantity production and vendor quotations have been solicited.

J.C. Proctor

GLOSSARY

AA	antiaircraft
AAOC	AA Operation Center
a-c	alternating current
AD	Air Defense
ADC	AD Command
ADES	AD Engineering Service
ADIZ	AD Identification Zone
ADPE	auxiliary data-processing equipment
ADSOD	Air Defense Systems Operation Division
ADW	Air Defense Wing
AEW	Airborne Early Warning
AF	Air Force
AFB	AF Base
AFCRC	AF Cambridge Research Center
AFIRO	AF Installation Requirements Office
AFMTC	Air Force Missile Test Center
AGC	automatic gain control
AGET	Advisory Group on Electron Tubes
AI	airborne interceptor
AMC	Air Materiel Command
AMIS	Air Movements Identification Service
AMP	American Marine Products
APL	Applied Physics Laboratory
AQL	average quality level
ARAACOM	Army Antiaircraft Command
ARDC	Air Research and Development Command
ARTCC	Air Route Traffic Control Center
ASC	Air Situation Coordinator
ASESA	Armed Services Electro-Standards Agency
ASO	Air Surveillance Officer
ASR	automatic send-receive
AST	Air Surveillance Technician
ASTM	American Society for Testing Materials
ATC	Air Training Command
ATCF	ATC Facility
ATO	Air Tactics Officer
ATT	Air Tactics Technician
B-N	bariated-nickel
BTL	Bell Telephone Laboratories
BSO	Battle Simulation Officer
CAA	Civil Aeronautics Administration
CAT	category
CBS	Columbia Broadcasting System
CC	combat center
CCDC	Cape Cod Direction Center
CDC	call direction code
CCS	Cape Cod System
CER	change evaluation request
C&E	communications and electronics
CHT	Charactron tube
CM	core memory
Codan	carrier-operated antinoise muting system
CP	Command Post
CPO	command pulse output
CRT	cathode ray tube
CS	coding specification(s)
DAB	display assignment bit
DACL	Dynamic Analysis and Control Laboratory
d-c	direct-current
DC	direction center
DCA program	the computer program for the active computer of a SAGE direction center
DCO	Design Control Office
DD	digital display
DDG	DD generator
DDL	Division of Defense Laboratories
DDR	digital data receiver
DDT	digital data transmitter
DGP	Data Generation Program
EADF	Eastern Air Defense Force
ECM	electronic counter measure
ECP	engineering change procedure
EMAR	experimental memory address register
EPSCOM	Equipment Program Services Committee
ESS	Experimental SAGE Subsector
ERA	Electronic Research Associates
FF	flip-flop
FGD	fine-grain data
FM	frequency modulation
FORX	FGD orientation with Raydist and calibrated Mark X
G/A	ground-to-air
GFI	gap-filler input
GSR	group selection register
HEC	Hazeltine Electronics Corp.
IBM	International Business Machines Corp.
ID	identification
IFF	identification - friend or foe
INS	interceptor simulator
IPS	initial program specification
IRE	Institute of Radio Engineers
JETEC	Joint Electron Tube Engineering Council

GLOSSARY (continued)

KSR	keyboard send-receive
LPO	Lincoln Project Office
LRI	long-range radar input
LTPS	Lincoln tube process specification
MAR	memory address register
MC	marginal checking
MCD	marginal checking and distribution
MDI	manual data input
MEL	minimum equipment list
M-G	motor-generator
MIL	military
MISP	Manned Interceptor Simulation Program
MITE	multiple input terminal equipment
MOC	Mission Operations Center
MPPS	Master Program Preparation Section
MTC	Memory Test Computer
NAS	Naval Air Station
NET&T	New England Telephone and Telegraph Co.
n-p-n	negative-positive-negative
NRL	Naval Research Laboratory
OB	output buffer
OMR	operational modification(s) request
OPS	operations
OT	Overlap Technician
PCC	Planning Coordination Center
PCD	power control distribution
PCO	Production Coordination Office
PIUMP	plug-in unit mounting panel
p-n-p	positive-negative-positive
PPI	planned position indicator
PRF	pulse repetition frequency
pps	pulses per second
PT	Plotting Technician
QPR	Quarterly Progress Report
RADC	Rome Air Development Center
RAFD	Rome Air Force Depot
RAND	Research and Development Corp.
RC	register containing
R-C	resistance-capacitance
RD	radar data
RECI	Request for Engineering Change and/or Information
RETMA	Radio, Electronics, Television Manufacturers Association
rf	radio frequency
ROTR	receive-only reperforator
S&EC	Scientific and Engineering Computation
SAC	Strategic Air Command
SAGE	Semiautomatic Ground Environment
SAHL	semiautomatic height-finder live
SAR	storage address register
SBT	surface-barrier transistor
SD	situation display
SDG	SD generator
SDV	slowed down video
SIF	selective identification feature
SIZ	security identification zone
SC	Signal Corps
SCEL	SC Engineering Laboratory
SO	Systems Office
SOP	standing operating procedure
SOT	Systems Operations Test
STINCO	SAGE-Talos Integration Committee
STP	System Training Program
SPIS	SAGE Program Identification Service
TAPE	Technical Advisory Panel for Electronics
TBS	training and battle simulation
TCAP	Tactical Channel Assignment Panel
TD	track data
TIR	Technical Information Release
TRACALS	Traffic Approach Control and Landing Service
TT	Texas Tower
UHF	ultra high frequency
VCM	vibrating coil magnetometer
VHF	very high frequency
WADC	Wright Air Development Center
WE	Western Electric Co.
WISE	Whirlwind I SAGE Evaluation
WL	warning light
wpm	words per minute
WSEG	Weapons System Evaluation Group
WSPO	Weapons System Project Office
WWI	Whirlwind I
XT	Crosstell, Crosstalk

SAGE OPERATIONAL PLANNING

GROUP 61

Israel, D.R., Leader

Anderson, H.E.
Boyd, H.W.
Cahill, J.J.
Fallows, R.S.
Garth, F.M.
Gochman, H.
Hauser, S.J.
Hedison, H.
Jeffrey, L.R.
Ladd, D.W.
Lafferty, E.L.
Levenson, Judith A.
May, J.P.
Ornstein, S.
Russo, R.F.
Slagle, J.R.
Stylos, P.
Wolf, E.
Woodward, W.B.
Zraket, C.A.

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I. SAGE OPERATIONAL PLANNING
GROUP 61

A. SUMMARY

The operational and mathematical specifications which define the air defense functions of a SAGE direction center are being refined to eliminate the inconsistencies and ambiguities that are revealed during the writing of the computer program. The specifications covering emergency capability and test-message sequences have been temporarily set aside in order to complete more pressing work.

The mathematical specifications for the simulated data generation programs for the Memory Test Computer are in preparation, and programming is already under way. A review of the requirements for ESS data reduction has been made, and programming has started. Responsibility for these activities has been transferred to Group 64.

The master specification for adapting the operational and mathematical specifications to SAGE direction centers has been drafted. The adaptation activity is now the responsibility of Group 67.

Satisfactory progress has been made on the preparation of operational specifications for the SAGE combat centers. Completion of both operational and mathematical specifications is scheduled for January 1957. The entire combat center activity has been transferred to Group 66.

New weapons systems are being studied with respect to their integration with SAGE. Representatives of Group 61 have attended and participated in five ADC meetings which were held to discuss employment of the F89H and F89J, F102A, F104A, BOMARC IM-99, Talos IM-70, and Army antiaircraft weapons in the SAGE system of air defense. The SAGE/F102A/MG-10 study, conducted jointly with Convair and Hughes, was concluded and a draft report was circulated to people concerned for their comments and recommendations. A SAGE-Talos IM-70 integration study was completed at the end of the quarter and a report is being written.

B. DIRECTION CENTER OPERATIONAL PLANNING

1. Operational and Mathematical Specifications

The task of preparing the operational and mathematical specifications for the SAGE direction center has been essentially completed. As Group 67 proceeds with the actual program preparation, a number of questions regarding the meaning, interpretation, or completeness of the specifications have arisen and Group 61 has been preparing supplements and corrections. Table I shows the status of the operational and mathematical specifications at the end of the quarter.

Preparation of proposed specifications for the emergency capability of the direction center and the test message sequences for the ground-to-ground data links* has been suspended in view of the fact that these features will not be programmed initially for ESS. Work on these specifications will await completion of other pressing tasks.

*MIT Lincoln Laboratory Quarterly Progress Report, Section I, Group 61 (15 June 1956).

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TABLE I

STATUS OF DIRECTION CENTER OPERATIONAL AND MATHEMATICAL SPECIFICATIONS

FUNCTION	OPS SPEC	MATH SPEC
1. Guide to Direction Center Operations	6M-3950 and Corr #1	None Required
2. Radar Data Inputs	6M-3774-1 and Corr #1,2,3	6M-3960
3. Track Detection and Initiation	6M-3766-1 and Corr #1,2	6M-4013-2
4. Automatic Tracking	6M-3836-2	6M-3953
5. Track Monitoring	6M-3826-2	6M-4020
6. Crosstelling	6M-3816 and Supp #1	6M-4150
7. Height Finding	6M-3828-2	6M-3997-1
8. Air Surveillance Station	6M-4030	None Required
9. Identification	6M-3780-2	6M-4028-1
10. Manual Input Data	6M-3814-2	6M-4032-1
11. Weather Data	6M-3778-2	None Required
12. Raid Forming	6M-3720-2	6M-3973-1
13. Subsector Command Post	6M-3795-2	None Required
14. Forward-Telling	6M-3810-1	None Required
15. Training and Battle Simulation	6M-3899-2	6M-4077 and Corr #1,2
16. Recording	6M-3989-2	6M-4086
17. Weapons Assignment	6M-3774-2	6M-3926 and Corr #1
18. Intercept Direction	6M-3786-2	6M-3927
19. Antiaircraft Direction	6M-3739-2	6M-3982-1
20. Digital Displays	6M-3870-1 and Corr #1	None Required
21. Situation Displays	6M-3951	None Required
22. Startover Function	6M-3930-2	None Required
23. Guide to Duplex and Standby Computer	6M-4141	None Required
24. Duplex and Standby Computer Operation	6M-4367	None Required
25. ESS Weather Station	6M-4242	None Required

2. Simulated Data Generation and Data Reduction

Progress has continued on the preparation of the simulated data generation and data reduction facilities, the programs which are being written for the Memory Test Computer. The operational specification for simulated data generation was issued as 6M-4067-1, "Operational Specifications for Simulated Data Generation" (18 May 1956); the mathematical specification is currently in draft form. Programming for this facility continues with expected completion date of December of this year.

The requirements for ESS data reduction have been reviewed and a memo proposing the nature and types of data reduction has been issued as 6M-4262 (Draft), "Proposal for Data Reduction Program," (6 July 1956). This draft proposes the following types of outputs:

a. Summary Outputs are concentrated information in the form of totals, averages, frequency distributions, percentages, etc. Two summary outputs are proposed: functional summaries and system summaries.

(1) Functional Summaries are summaries of items pertaining to particular system functions (e.g., radar inputs, identification, intercept direction). These will be in a form probably useful to only persons familiar with the particular function.

(2) The System Summary is selected parts of the functional summaries and is indicative of over-all system operation. This is the closest approach to ADC summary reports required for higher command.

b. Log Outputs are listings of events as they occur, including such things as switch actions and status changes.

(1) The System Log is a summary of the operation of the system which will include start and stop times of various equipments (computers, radars, DC stations, etc.) and possibly reasons for them. This will be used in connection with the system summary above.

(2) Station Logs are records of all actions taken by a particular station and all alarms occurring at the station.

(3) Track Action Logs are records of all actions taken on a particular track and any other important automatic events that occur during the life of the track (initiation, identification, and similar track status changes).

c. History Outputs are frame-by-frame printouts of information, most of which will probably change every frame.

(1) Track History Printouts are frame-by-frame printouts of many of the quantities normally carried in the system for each track, including position, velocity, track merit.

(2) Correlated Data Printouts are supplements to the track history for those tracks which have been designated for the special recording of correlated data. Although the special recording is done on a subframe-by-subframe basis, the printout will be on a frame-by-frame basis.

(3) Incident History Printouts consist of events (actions, histories, and logs) leading up to and following certain specified incidents such as identification, trouble detection and monitor assignment, and weapons assignment.

(4) Item Printouts are frame-by-frame histories of selected items not included in the histories of (1), (2), and (3) above, e.g., summary counts of track status changes and radar input count.

GROUP 61

During August of this quarterly period, responsibility for the data-generation and data-reduction facilities was transferred to Group 64.

3. Adaptation

The master adaptation specification and detailed adaptation specification described in the previous quarterly have been combined and issued as a single document: 6M-4406 (Draft) "Master Adaptation Specifications for SAGE Direction Centers" (1 August 1956). This document, the responsibility for issuing it in final form, and the responsibility for preparing the detailed adaptation specification for ESS were turned over to Group 67 during August.

D. R. Israel
C. A. Zraket

C. COMBAT CENTER OPERATIONAL PLANNING

Preparation of the operational specifications for the SAGE combat centers has continued. Present status of these specifications and other documents is shown in Table II. It will be noted that all of the operational specifications have either been issued as 6M-series memorandums or are in draft form. No significant progress has yet been made on the mathematical specifications. Target date for completion of both sets of specifications is 1 January 1957.

TABLE II
STATUS OF COMBAT CENTER SPECIFICATIONS

A. OPERATIONAL SPECIFICATIONS

Subject	Status
1. Guide to Joint Combat Center Operation	6M-4031 issued 17 April 1956
2. Sector Command Post Staff and Liaison Personnel	6M-4247 issued 8 August 1956
3. Air Surveillance	6M-4248 to be issued in September
4. Weapons Allocation	In draft form
5. Manual Inputs	6M-4251 issued 25 July 1956
6. Crosstelling, Forwardtelling, Backtelling	In draft form
7. Training and Battle Simulation	6M-4252 issued 26 July 1956
8. Recording	6M-4253 issued 30 July 1956
9. Situation Displays	In draft form
10. Digital Displays	In draft form
11. Guide to Duplex and Standby Operation	6M-4527 issued 8 August 1956

B. OTHER DOCUMENTS

1. AN/FSQ-8 Console Equipment and Label Layouts	6M-3732-2 issued 6 July 1956
2. AN/FSQ-8 Digital Display Slot Assignment	6M-4237 issued 31 March 1956; Supplement #1 issued 25 June 1956
3. AN/FSQ-8 Category and DAB Assignment	6M-4257 issued 27 April 1956; Supplement #1 issued 22 May 1956

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During August of this quarterly period the responsibility for completion of the combat center specifications and for the preparation of the actual program was transferred, with the staff previously assigned to that activity, to Group 66.

D. R. Israel
C. A. Zraket

D. WEAPONS INTEGRATION

Lincoln's effort in the general area of weapons integration has continued on a modest scale with about eight staff members from Group 61 assigned to the activity. This effort continues to be one of learning and defining the problems and contributing to the preliminary planning for organized solution of these problems. During the quarter, Group 61 participated in five ADC employment meetings, concluded a joint study (with Convair and Hughes) of the SAGE/F-102A/MG-10 integration, and continued a joint study (with RCA and John Hopkins Applied Physics Laboratory) of the SAGE/IM-70 (Talos) integration.

It is expected that the next quarter will see the conclusion of the Talos integration study and the completion of the first-pass employment meetings on the planned ADC weapons. Additional detailed integration studies are being considered, but none are planned now because of manpower limitations and the need for a general clarification of the modus operandi to be followed with regard to this area of work.

1. Employment Meetings

In order to utilize the control potential which the SAGE concept represents, it is necessary to spell out in detail the role which each weapon will play in a future air battle, the manner in which it will play its part, the effect which its presence will have on the general conduct of the battle, and the support and restrictions which SAGE control should provide. As a first step toward providing this information, ADC has conducted six meetings during the past four months to discuss the employment of the following weapons: F89H & J, F102A, F104A, BOMARC (IM-99), TALOS (IM-70), and antiaircraft weapons. Similar meetings on the F101B and F106A are planned for the near future. The meetings have been attended by representatives of Headquarters ADC, 4620th Air Defense Wing, Headquarters USAF, Headquarters ARDC, AFCRC, Lincoln, RAND, WSEG, and the individual weapon contractors.

These employment meetings have considered each weapon together with SAGE as an air defense entity, with as yet no detailed consideration of the problems of all weapons being simultaneously employed. The resulting conference notes published and distributed by ADC, provide a basic plan from which future integration work can evolve.

2. F-102A

a. SAGE/F-102A/MG-10 Integration Report

The report of the joint Convair, Hughes, and Lincoln Laboratory committee, established last March to study SAGE/F-102A/MG-10 integration, was published in draft form on 11 June 1956. The report deals with the integration problems as foreseen by the committee and estimates the man-month requirements to solve these problems and to implement the planning, programming, and testing deemed necessary for employing the F-102A to its fullest capability in the SAGE

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environment. Comments and criticisms are being solicited from the Convair, Hughes, and Lincoln Laboratory managements with the intent to incorporate these into a rewrite of the report and a subsequent republication of it in final, approved form.

b. F-102A Employment Meeting

The employment meeting for the F-102A Interceptor was held at ADC Headquarters at Colorado Springs during the week of 18 June. This was followed up by ADC's publication of "Employment of the F102A Interceptor in SAGE Era."

The more important new features of the F-102A are: supersonic speed, homing missile armament (Falcons), snap-up capability and automatic flight control after AI radar lock-on. Major problems in the use of this weapon in SAGE include data link standards and pilot displays, tracking of supersonic aircraft, fuel computations in the SAGE vectoring program, pressure altimeter and electronic height-finder inaccuracies, and scramble procedures.

3. F-89 H & J Employment Meeting

During the week of 16 July, ADC held an employment meeting at Northrup Aircraft at Hawthorne, California, to consider the problems occasioned by introduction into SAGE of the F89H and F89J interceptors. The former carries Falcon missiles; the latter MB-1 nuclear warhead rockets. Major consideration was given to the effects of a nuclear blast upon AI radar, pilot, and airplane.

4. F-104A Employment Meeting

The near-Mach-two speed capability and Sidewinder armament restriction of the F-104A interceptor presented special problems for the F-104A SAGE employment meeting which convened at Lockheed Aircraft Corporation, Burbank, California, between 23 and 27 July 1956. Of significance to SAGE was the revelation that the F-104A through a combined "zoom" and "snap-up" tactic can be effective against threats as high as 65,000 feet. However, the infrared seeker of the F-104A's Sidewinder missile restricts all approach angles to the target's rear hemisphere. For the normal interception this will force the F-104A into final turns of between 90 and 180 degrees.

5. BOMARC

Although not all of the recommendations in the SAGE/IM-99 compatibility report* have yet been implemented, progress has been made in some areas of the BOMARC integration.

Experimental firings of BOMARC missiles will be conducted at AFMTC (Patrick AFB, Florida) under control of a SAGE-like computer program in the XD-2 computer located at Kingston. These tests are scheduled to start late in 1957. The computer program, to be modeled after SAGE, is being written by IBM.

Boeing has established a small group of people at Lincoln to become familiar with the SAGE System and computer program. They will work, with Lincoln assistance, on the planning of the operational and mathematical specifications for revision to the SAGE program to permit

*MIT Lincoln Laboratory Quarterly Progress Report, Section I, D. (15 June 1956).

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integration of BOMARC. The availability of the compatibility report and the ADC employment plan has substantially assisted this effort.

Continuation of the study of BOMARC operation with the SAGE System has pointed out two important problems. The present ground-to-air data link equipment (airborne and ground) does not permit switching the receiving frequency of a missile as it crosses a SAGE subsector boundary. As a result, guidance commands must continue to come from a single transmitter and a single SAGE direction center for the full intercept time. Therefore, procedures for tracking and handing over control of manned interceptors as they cross boundaries are not applicable; second, the BOMARC will require different techniques for handling missile information which otherwise would be crosstold between direction centers. Future BOMARC squadrons will very likely have time-division data-link with an airborne frequency switch to facilitate handover of missiles as they cross subsector boundaries.

A second problem pointed out by the operational studies has been the Mark X beacon used by BOMARC. The general problem of overinterrogation from the ground will mean excess retruns and interfering responses under heavy traffic conditions. This will result in confusion in the tracking and initiation process. Since high firepower is one of the main characteristics of BOMARC, many BOMARC tracks may need to be initiated rapidly in small areas. The SIF code confusion can seriously hinder this. In addition, the airborne diversity antenna tends to be somewhat incompatible with the statistical requirements for signals to the FST-2.

6. Talos

The employment meeting for the Talos (IM-70) interceptor missile was held at RCA, Moorestown, New Jersey, on 4 to 8 June 1956. A plan was made to automatically assign hostile tracks to Talos detachments, with manual override facilities. No human actions would be required under normal conditions from the identification of a track as hostile to its destruction by a Talos missile. A conference report entitled "Employment of Talos (IM-70) in the SAGE Era" has been issued by ADC.

At the request of ARDC (Detachment #1), a study group was formed to examine the problem areas associated with SAGE-Talos integration and to recommend solutions. Representation included RCA, APL, Lincoln, IBM, ADES, and ARDC. This group held three meetings in the period June to August 1956: at RCA (25 to 29 June); APL (6 to 10 August); and at ADES (28 to 31 August). The committee concerned itself solely with the technical problems arising from the implementation of the ADC employment plan and expects to complete its report during the next quarter.

7. Antiaircraft Weapons

The SAGE operational and mathematical specifications prepared for Army antiaircraft weapons have been considered only as tentative specifications for use in preparing the initial program. This "tentative" nature derives from the lack of an official description of the employment of antiaircraft weapons in SAGE. During this quarter, Lincoln has assisted both the Air Force and Army as they have attempted to resolve the role of the Army's AAOC and AN/FSG-1 "Missile Master" when operating with SAGE.

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The employment meeting for antiaircraft weapons was held in Baltimore, Maryland, at the Glenn L. Martin Company, from 9 to 17 August 1956 and a report entitled the "Proposed Employment of Antiaircraft Weapons in the SAGE Era" was written. This report documents a method for the employment of antiaircraft weapons under the concept of centralized control. The selection of tracks for engagement by NIKE and the assignment of these tracks to specific batteries will be performed at the SAGE direction center; assignments are to be transmitted to the batteries through the AN/FSG-1. Communication from the direction center to the AN/FSG-1 will be by 750 pps data service; status information is to be returned through 1300 pps service.

R. S. Fallows
H. Anderson
F. Garth
L. Jeffrey
J. May
E. Wolf

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ESS INSTALLATION

GROUP 62

O'Brien, J.A., Leader

Aronson, I.
Barrett, B.W.
Callahan, R.J.
Canty, W.J.
Carter, C.J.
Clarke, J.D.
Coffin, S.T.
Crane, J.D.
Durgin, F.R.
Flanagan, M.J.
Gano, J.J.
Gerhardt, R.H.
Ginsburg, S.B.
Giordano, J.
Hingston, A.
Irish, F.E.
Jahn, R.C.
Paddock, R.B.
Sandy, F.G.
Sandy, T.J.
Sutro, L.L.
Werlin, A.M.

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II. ESS INSTALLATION
GROUP 62

A. SUMMARY

BTL test specifications were used for the first time in subsystem testing during this quarter. The height-finder subsystem using XD-1, has successfully tracked a live aircraft. Encouraging data was obtained from height-finder accuracy tests performed between South Truro and Whirlwind I, corroborating data obtained earlier in the year. The unavailability of computer time has hampered subsystem testing and necessitated rescheduling to insure that the testing essential to ESS shakedown tests will be completed by the time the particular subsystem is needed.

Two groups of engineers are working on the long-term problems of system checkout techniques. One group is studying the problem and writing computer programs which will expedite such checkouts; the other group will coordinate maintenance activities and perform the system checkouts as the techniques are debugged.

Arrangements have been made between IBM, Lincoln, and the Air Force to permit and finance, on short notice, small changes to ESS equipment. This arrangement should materially expedite equipment testing and acceptance.

The Bendix LRI monitor consoles arrived during the quarter. Some design deficiencies in them were discovered during testing and Bendix is working to clear up the troubles.

Testing of the commercial hardware to be used in the XD-1 centralized probe system has been completed and installation of the system is expected to begin during the next quarter.

J. A. O'Brien

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B. ESS SUBSYSTEMS

1. General

Test specifications were completed by BTL for long-range radar inputs and height-finder subsystems toward the end of the quarter. Initial testing with the height-finder specifications was gratifying – XD-1 tracked a live aircraft during one of them. Subsystem testing of the Bath long-range radar input was started but no significant results were obtained due to difficulties that arose from shakedown of site equipment, lack of computer time, and trouble with the telephone lines.

2. Height-Finder

a. XD-1

Of four semiautomatic height-finder subsystem tests scheduled between XD-1 and Bath or South Truro, two between XD-1 and Bath were accomplished. The first resulted in 93.4 per cent replies. The ten "no reply" errors experienced were attributed to either the AN/FST-2 or the phone line. An additional print character received with every reply was attributed to XD-1. The many errors experienced during the second Bath/XD-1 test were attributed to the phone line connection to Bath. Bath had reported that they were missing timing pulses which in turn caused them to miss a request and send back a "no reply".

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b. WWI

Seven tests were scheduled between WWI and South Truro during the quarter. Four were cancelled because of equipment not operating – one for phone lines, two for fine-grain data machine, one for search radar. Two tests were cut short because of aircraft difficulty and bad weather which resulted in poor tracking. However, two tests were run from which fairly satisfactory data was obtained. The last test of the quarter gave four hours of good data which was in 95 per cent agreement with results of tests run earlier in the year. Returns were 95 per cent accurate within ±2000' and 50 per cent accurate within ±1100' which approaches the accuracies reported last winter.

3. Crosstelling Links

Five tests were run with 1 to 5 errors out of 5000 messages. The errors were caused by XD-1 output system which IBM is correcting.

Since the crosstelling function will not be needed for some time, reliability tests on this subsystem were suspended early in the quarter. Testing will be resumed as soon as the need for the subsystem is anticipated.

4. Ground-to-Air Data Link

Attempts to use some severe format programs failed during this quarter and the trouble was traced to the demultiplexers. Investigation brought out the need for recommendations from G.E. and they have indicated that they will visit Lincoln Laboratories. Subsystem tests meanwhile have been held up except for a new correlation test that was tried out at the Lexington Field Station. The BTL test specification, based on the Lincoln Laboratory test concept, was written and, although not in final form, spells out all ground-to-air data-link subsystem tests.

5. Automatic Teletype Outputs

Subsystem testing on automatic teletype outputs was held up throughout the quarter due to unavailability of computer time for both checking out the computer program for the subsystem and testing the subsystem itself.

6. Ground-to-Air Voice Radio

Subsystem testing was completed on the ground-to-air voice radio by Western Electric under the guidance of John Hansen of Group 311, who published the report.

7. External Wire Communications

Subsystem testing of external circuits has been rescheduled according to when they will be needed for ESS shakedown tests. They have been broken up into four groups, the first of which must be tested and available for shakedown by 3 December 1956. Testing is scheduled to be complete on the second group by 4 March 1957, on the third group by 3 June 1957, and the fourth group sometime after October 1957. Some circuits that will not be needed until 1958 have been cancelled or suspended and will be reinstalled when the need for them arises.

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8. Maintenance Studies

Initial studies of the maintenance that will be required for ESS subsystem equipment (both within and remote from Bldg. F) showed an immediate need for brief checks, of the status type, of the equipment in Bldg. F itself. A Lincoln-RAND study group made initial plans for about 15 operators to check all displays, switches, and light guns.

9. Maintenance Coordination

A team composed of representatives from each organization concerned, both Lincoln and outside, was set up to maintain ESS equipment. The purpose of the team is to perform efficient, on-the-spot maintenance to the equipment, so vital to ESS operation, without the usual administrative and organizational boundaries that might cause costly delays. Under the general guidance of the Maintenance Coordinator, the team covers the following equipment:

Equipment	Organization Represented
Data Inputs	Division 2
Computer and Displays	IBM
Telephone Facilities	NET&T
Ground-to-Air Radio	Division 3
Ground-to-Air Data Link	Division 3
Bldg. F Power and Air Conditioning	Division 1

Most of the quarter was spent acquainting members of the team with ESS equipment and operation and making preliminary plans for the maintenance coordination activity.

10. XD-1 Reliability

The AN/FSQ-7 (XD-1) computer performed with an average reliability of 79 per cent during this quarter. The mean good time between failures was 1.2 hours. The relatively poor performance of the computer during this period was at least partly due to the discontinuance of marginal checking. IBM conducted an extensive reinspection and touching up of the cabling and pluggable units to verify that mechanical specifications were met. This activity used maintenance time normally available for marginal checking.

I. Aronson
T. J. Sandy
C. J. Carter
R. B. Paddock
A. M. Werlin

C. CIRCUIT SUPPORT

1. LRI Monitor

The Bendix LRI monitor consoles arrived and were installed during the quarter (Fig. 62-1). Group 62 used a test pattern, generated by MTC, and some inadequacies were indicated in the Bendix design. One of the major difficulties is a prf problem in the console deflection system. Bendix has been alerted and is working to clear up the deficiencies.

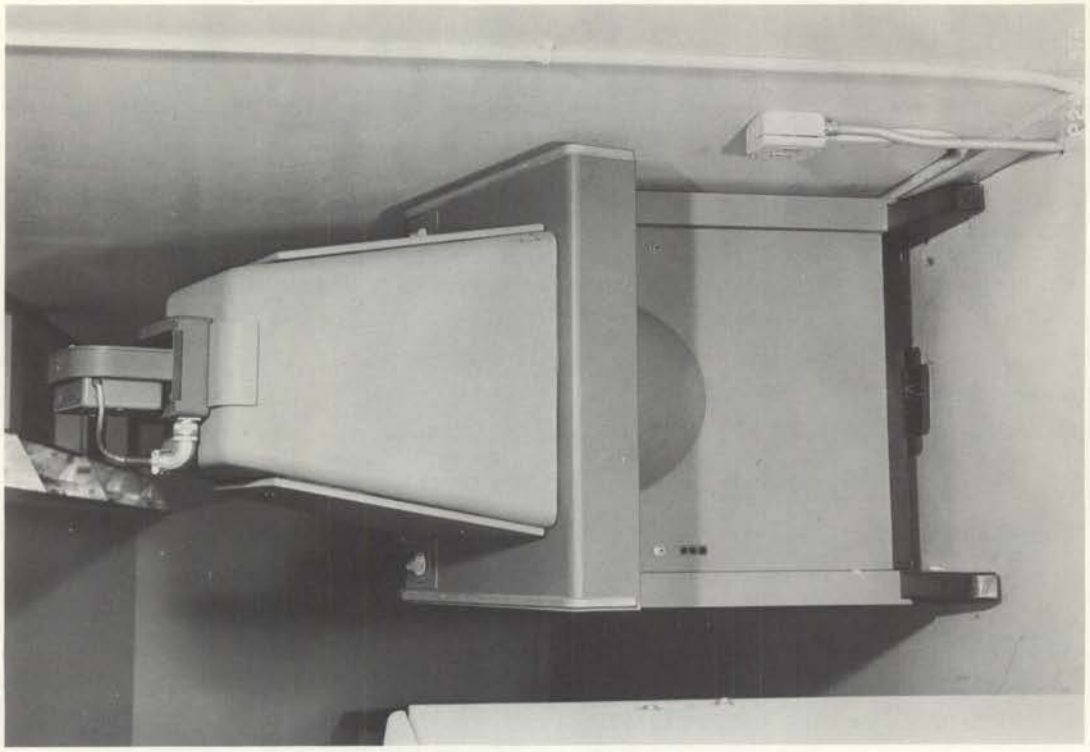


Fig. 62-1. Bendix LRI monitor consoles. (a) Mapper display console and auxiliary console; (b) camera console behind (a).

2. Centralized Probe System for XD-1

A probe system has been designed which will provide at the operating console a comprehensive display of computer waveforms, thereby enabling centralized direction of maintenance activities. Two systems were designed and installed on XD-1, using a 6197 cathode follower, the other one is completely passive using no vacuum tubes or other active elements.* Because of its simplicity and on the basis of tests performed, the passive system will be used in XD-1 and has been recommended for use in the AN/FSQ-7 and -8 computers. The system in XD-1 will consist of approximately sixty 200-foot cables between the frames on the computer floor and a patch panel at the operating console beside a Tektronix 545 oscilloscope (Fig. 62-2). The probe gun carries 27 feet of coaxial cable to a connector which plugs into a permanently mounted jack on the computer frame. Fig. 62-3 compares typical computer pulses and flip-flop waveforms received over the XD-1 227-foot probe system with those of the standard 42-inch Tektronix P410 probe. The P410 probe waveforms in A of Fig. 62-3 differ only slightly from the 227-foot probe waveforms shown in B. Transient distortions of the long probe, while not zero, are insignificant for maintenance work.

Testing of commercial hardware for the XD-1 probe system has been completed. Western Electric jacks and Federal CE 330 cable will be used. The design of the system and the test data taken has been published in 6M-4283.**

3. Probe System for MTC

A passive probe system has been developed for the Memory Test Computer** which is used in much the same way as that for XD-1 (Fig. 62-4). MTC is a considerably smaller computer than XD-1 and 55 feet of cable is enough to reach any test point in the computer from an oscilloscope at the operating console. Installation and testing of the MTC probe system has been completed and operation is satisfactory.

4. Digital Data Converters

Radar data in the SAGE System will be transmitted over telephone lines to a central data service provided by the telephone company. The data is then transmitted to a direction center computer in the form of 1-volt signals at a rate of 1300 to 1600 cps over each of three phone lines. All SAGE computers use standard 0.1-μsec pulses and a circuit, termed a digital data converter, has been designed to convert the 1-volt signals to the 0.1-μsec pulses. Each LRI site will require two converters, each GFI site one. Four breadboard models of the digital data converter have been installed and tested in Building F (Fig. 62-5). IBM equipment is expected to replace the Lincoln-built circuits.

R. J. Callahan
B. W. Barrett
F. R. Durgin
A. Hingston
M. J. Flanagan

*MIT Lincoln Laboratory Quarterly Progress Reports, Section II, Group 62 (15 March and 15 June 1956).

**Santelmann, W.F., Jr., and Hingston, A.J., "Centralized Probe System" MIT Lincoln Laboratory Report 6M-4283 (22 June 1956).

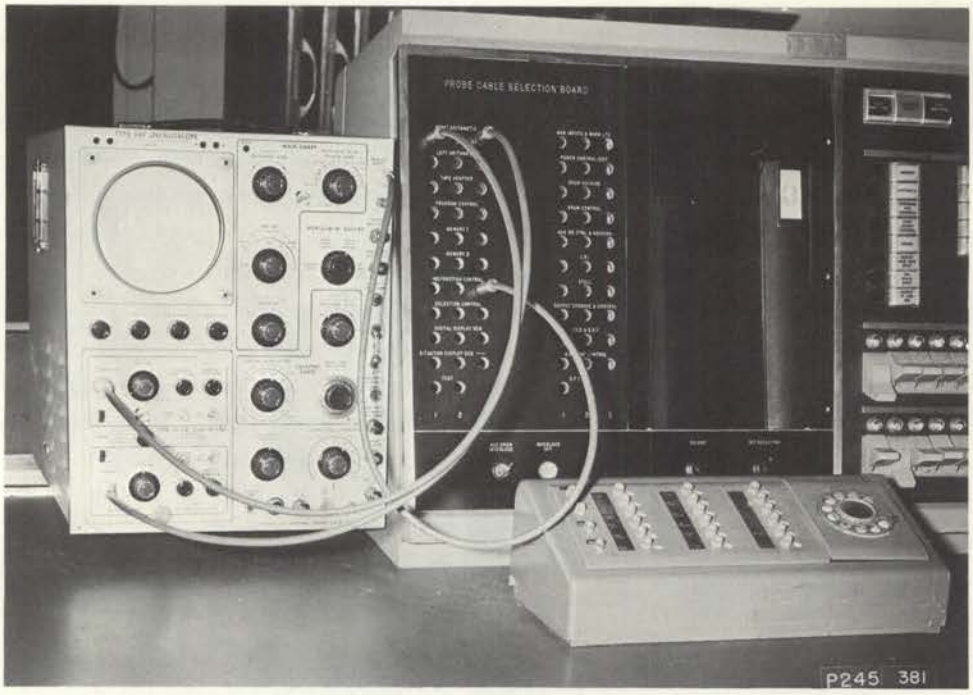


Fig. 62-2. Centralized probe system for XD-1 showing Tektronix 545 oscilloscope and patch panel.

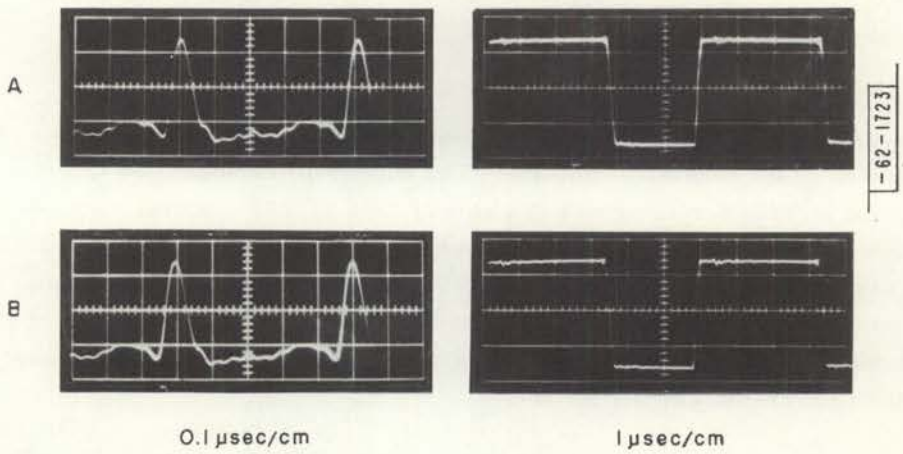


Fig. 62-3. Probe response comparison on computer waveforms. (a) Tektronix P410 waveform; (b) 227-foot centralized passive probe waveform.

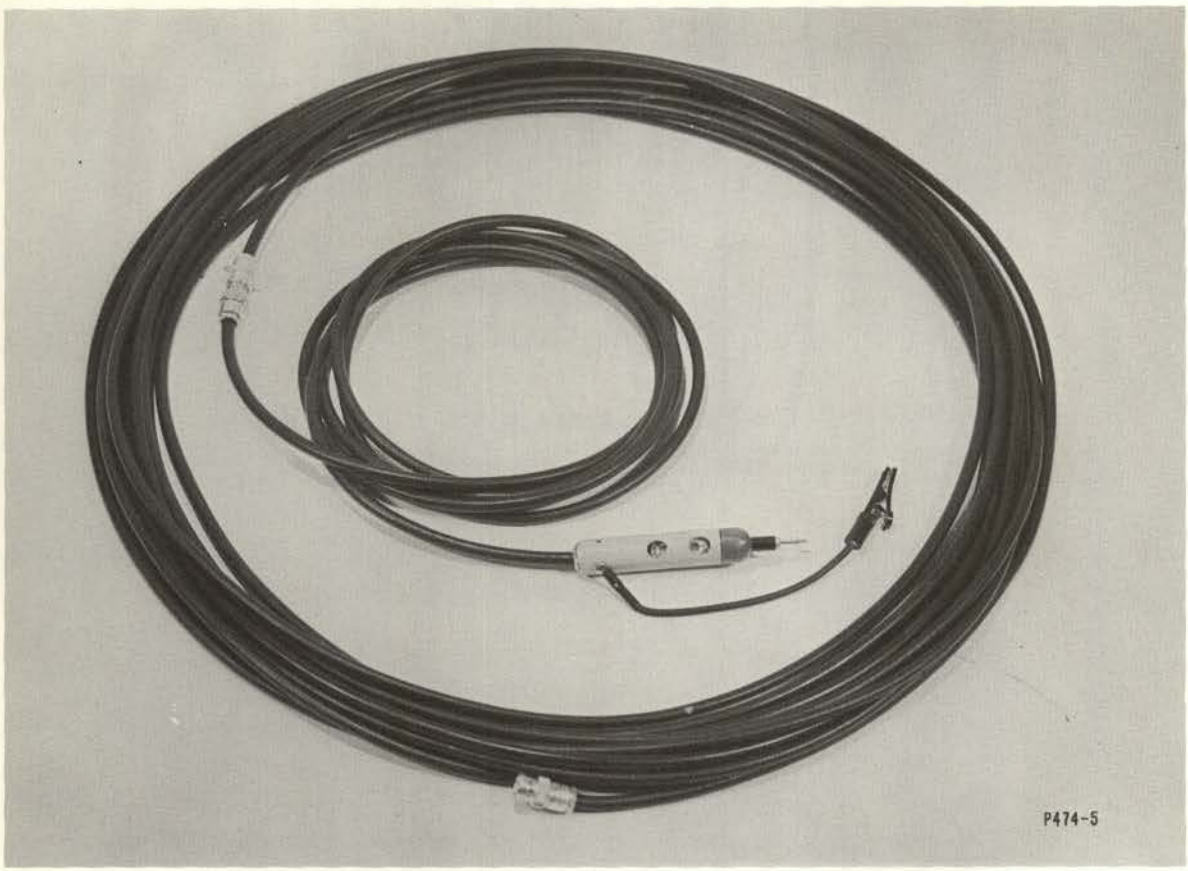


Fig. 62-4. 55-Foot passive probe system for MTC.

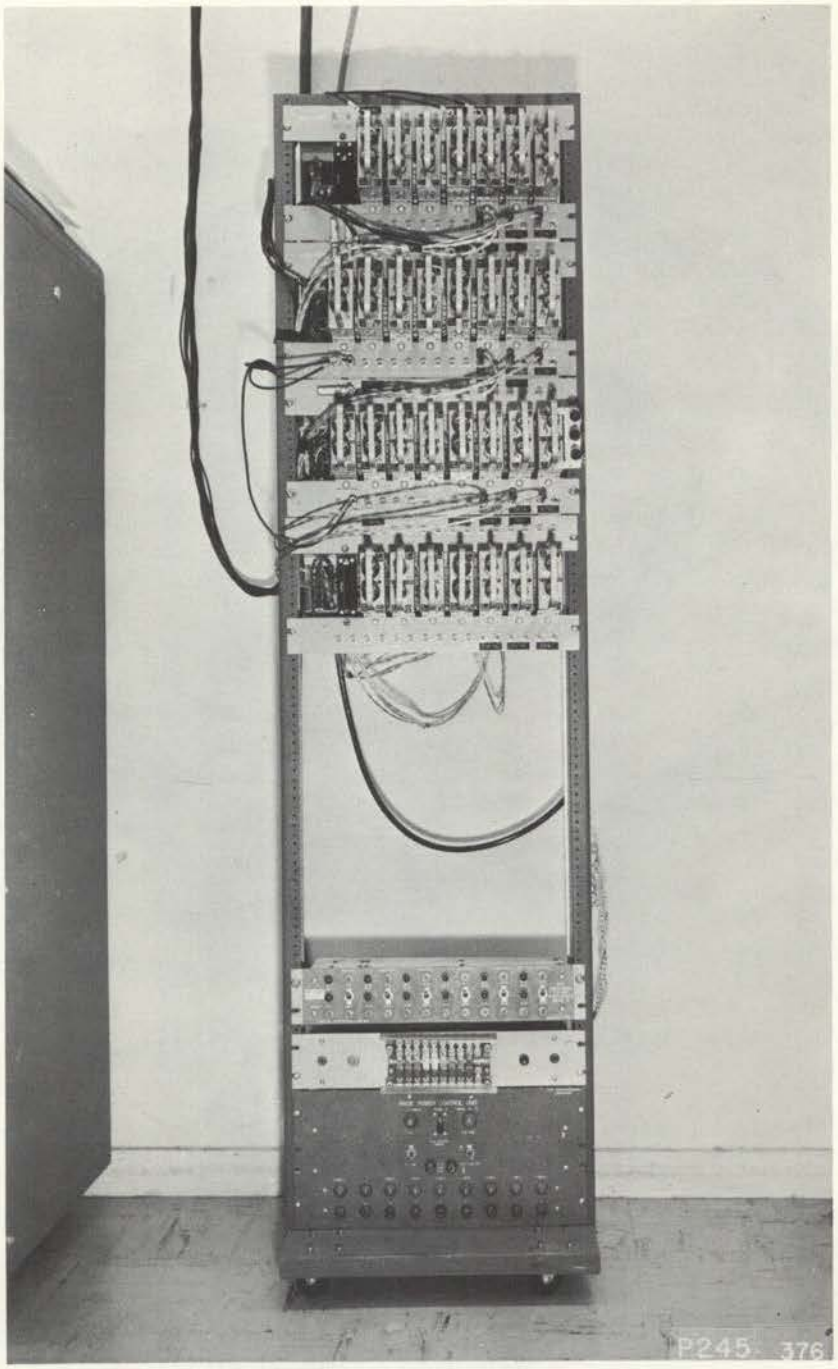


Fig. 62-5. Digital data converter for Building F – breadboard model.

D. POWER

1. XD-1

General Electric Company has modified the XD-1 Bank A d-c supplies, bringing their performance up to that required by the IBM purchase specification. Bank B supplies will be modified during the next quarter.

Considerable trouble has been experienced in the power system of XD-1 due to its inability to override utility line transients. Part of the trouble has been corrected by removing the phase-balance and undervoltage relays on the motor side of the motor-generator sets. The other major trouble is attributed to the a-c control coils on the contactors which supply a-c power to the d-c power supplies. These coils will be replaced with d-c operated coils.

2. Magnetic Amplifiers

Preliminary investigation of magnetic amplifiers* has shown that they can be used to replace the power control relays in large electronic systems such as the AN/FSQ-7 computer. These units should be much more reliable than the relays now used because they have no moving parts and use components that have inherently long-life characteristics. An extensive investigation of their operating margins is being made.

3. D-C Power Supplies

Two d-c power supplies, which use transistor regulators driving a final magnetic amplifier power stage, have been built and tested (Fig. 62-6). One, a 15-volt, 8-ampere unit is used for general laboratory distribution. The other, a 10-volt, 50-ampere unit, is being used in TX-2. Since these supplies have only static components in their design, they should prove extremely reliable.

J. J. Gano
G. F. Sandy
J. D. Clarke
S. T. Coffin
R. C. Jahn
J. Malouin

E. DESIGN CONTROL OFFICE

All proposed changes to the equipment, computer program, or operation of AN/FSQ-7 (XD-1), AN/FSQ-7 or AN/FSQ-8 are studied and recommendations made on them by the Design Control Office (DCO) who also obtains the necessary concurrence from the organizations concerned. Installation and availability dates for changes that are to be made to both prototype and production machines have been coordinated between IBM and Lincoln Laboratory to insure compatibility.

A review has been made of IBM rewrites of original specifications for the AN/FSQ-7 and -8, which were written to (1) consolidate and clarify the original specifications and (2) describe the equipment as it exists. The review was made with the cooperation of Group 67 and proved helpful in revealing minor incompatibilities.

*MIT Lincoln Laboratory Quarterly Progress Report, Section II, Group 62 (15 June 1956).

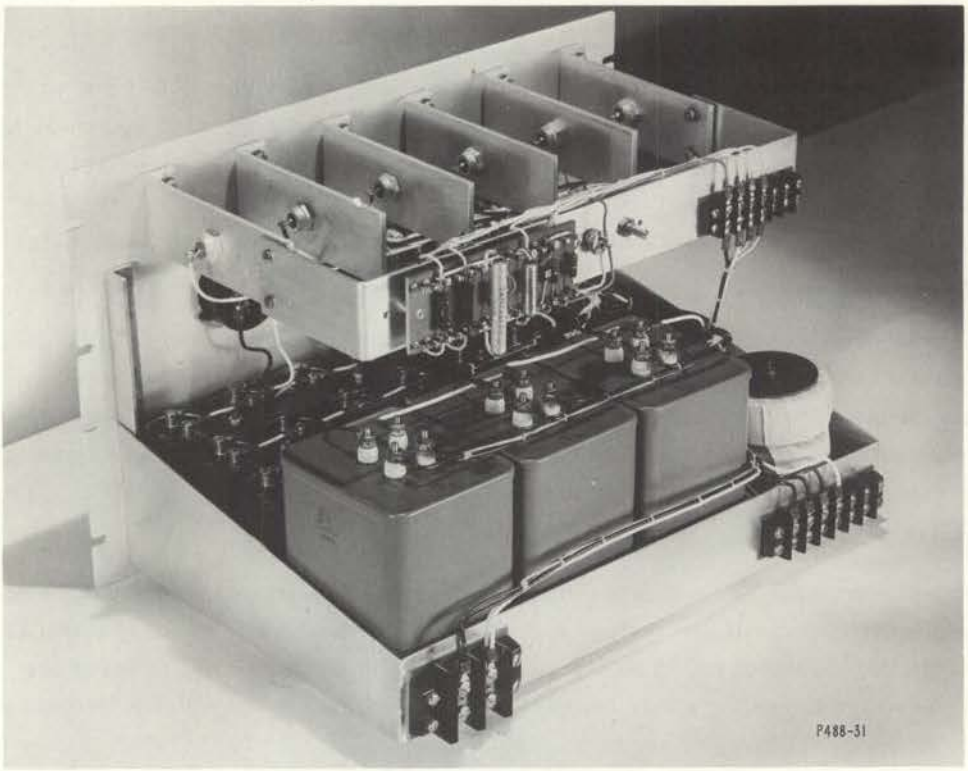


Fig. 62-6. Transistor-regulated d-c power supply for TX-2.

The following changes and additions were among those made to XD-1:

1. Bendix LRI monitors were installed.
2. The teletype output facility was expanded to provide for 25 outputs, instead of the original 5.
3. Filters were installed on the digital display tubes to increase readability.

The following changes and additions to AN/FSQ-7's and -8's have received IBM-MIT concurrence:

1. GFI Input Element

It was agreed that gap-filler input facilities should operate at 4 to 10 rpm instead of 2 to 4 rpm. We have no radars operating at less than 4 and the trend seems to be such that the rpm of radar antennas will increase.

2. Magnetic Tape Equipment

The magnetic tape equipment was such that in some instances programming restrictions were imposed after an operate rewind instruction had been given; the magnetic tape equipment will be modified.

3. Test-Pattern Generator

Connections between the test-pattern generator and the phone-line interconnection unit were added to allow information generated by the TPG or the standby computer to be placed on telephone lines. These connections will facilitate testing of remote equipment.

4. LRI Input

A revision to the parity check circuits at the input to LRI channel equipment now provides a parity check for each of the two words in an LRI message. Previously, the parity was checked on a message basis and an error that occurred simultaneously in every LRI word would not be detected.

5. Display

Normal area-assignment switches will be added to display consoles. These switches will facilitate the changes required to adapt the consoles for control in different portions of the area covered by a direction center or a combat center.

J. D. Crane
R. H. Gerhardt
S. B. Ginsburg
J. Giordano
L. L. Sutro

ADVANCE DEVELOPMENT

GROUP 63

Brown, D.R., Leader

Best, R.L.
Bradspies, S.
Brown, D.L.
Clark, W.A.
Corderman, C.L.
Croft, W.J.
Davidson, G.A.
Downing, J.L.
Dugger, C.O.
Eckl, D.J.
Fadiman, J.R.
Farley, B.G.
Fergus, Patricia
Forgie, J.M.
Frankovich, J.M.
Goodenough, J.B.
Gould, R.H.
Guditz, E.A.
Gurley, B.M.
Highleyman, W.H.
Keith, Elaine
Kirk, C.T., Jr.
Konkle, K.
Kriensky, J.
Maddocks, F.S.
Menyuk, N.
Mitchell, J.L.
Olsen, K.H.
Pacl, R.A.
Papian, W.N.
Petersen, M.
Peterson, H.P.
Santelmann, W.F.
Smith, D.O.
Weiss, G.
Wickham, D.G.
Wold, A.
Zieman, H.E.
Zopatti, R.C.

III. ADVANCE DEVELOPMENT
GROUP 63

A. SUMMARY

TX-0, an experimental, 18-bit, digital computer is being expanded to a full 36-bit machine designated as TX-2. TX-2 will have the use of the 256 × 256 × 38 (2.5 million bit) memory, plus the completely transistorized 64 × 64 × 37 memory which uses the new 50-30 mil cores. Improved and more extensive transistor circuitry and packaging, over that of TX-0, will be incorporated in TX-2. The design of TX-2 permits the concurrent operation of several input and output devices, making it essentially a number of logically separate computers which use the same memory, program, and arithmetic elements. Although TX-2 is a single-address system, its 36-bit registers in the arithmetic, exchange, and control elements can be addressed directly by all instructions as well as indirectly by load and store instructions, thereby retaining much of the flexibility of a double-address code without sacrificing the simplicity of a single-address code.

Twenty of the 38 planes of the 256 × 256 × 38 memory for TX-0 had been assembled in the memory stack by the end of the quarter. Adjustments are nearly completed and the stack of 20 planes is expected to be operating early in September.

A tape-drive system has been designed for TX-2 which is expected to eliminate the mechanical complications and, therefore, much of the extensive maintenance required by most commercially available computer tape drives. The design will allow reading over a wide range of tape speeds.

Sample 4 × 4 memory planes were constructed using printed circuits to link the cores together instead of the conventional wiring. Several methods of printing the circuits are being evaluated.

Thin films of 80-20 Permalloy have been vacuum-evaporated and preparations are being made to develop circuits that will use thin films of magnetic materials as memory (information-storage) elements in digital computers.

A study of the switching characteristics of Philco surface-barrier transistors has been completed. The study disclosed that several independent, relatively easy to measure, sets of parameters may be used to specify the switching transistor, instead of the difficult measurements of forward and inverse cutoff frequencies.

A new, micro-alloy transistor, type L-5134, developed by Philco, is in pilot-line production. Driving circuits which must supply high currents are already being designed to use the L-5134 because of its high grounded-emitter current gain.

Transistor life tests through August show a failure rate of 0.06 per cent per 1000 hours of operation.

D. R. Brown W. N. Papian
C. L. Corderman

B. MAGNETIC MATERIALS

1. Introduction

The magnetic materials section develops, and supplies to Lincoln Laboratory, magnetic materials for digital-computer applications. Lincoln Laboratory computers are used in real-time

control problems which require from the computer components

(a) reliability
(b) speed
(c) ready assembly of large numbers
(d) low cost.

The solution to the problem of memory, or information-storage, of the computer has been the design of a coincident-current, magnetic-core matrix, which has placed additional restrictions on the magnetic material to be used as the storage element. In addition to the above four engineering requirements, the individual components must have

(e) square hysteresis loops
(f) uniform electrical and magnetic properties
(g) operating power levels low enough to be compatible with the speed requirements.

The above three requirements have given sharp definition to the development program for magnetic materials.

In general, systematic magnetic-material development, for any practical device such as the coincident-current memory for digital computers, includes several steps. First, the engineer puts a magnetic material into his practical device and measures the quality of the material in terms of parameters which are relevant to that particular device; these are the engineering parameters, and material specifications are written in terms of them. The ceramist or metallurgist who must process the materials according to the engineering specifications has as his variables the chemistry and the physical state of the material. Before the best production process can be worked out, therefore, the engineering parameters must be expressed in terms of chemistry and physical state. Expression of the physical state is done in two steps. First, the macroscopic mechanism by which magnetism and magnetic changes occur are worked out on a semiclassical model. In this step, the engineering parameters are expressed in terms of the physical state of the material (grain size, density, geometry, homogeneity, etc.) and more fundamental properties of the material (saturation moment, Curie temperature, magnetic anisotropy, magnetostriction, electrical conductivity, etc.). The final step is to understand the relationship between the chemistry of a material and the more fundamental properties. This final relationship, which is significant for any practical device, requires a profound understanding of the origin of magnetism and the chemical bond.

Over the past four years, the engineering parameters that are important to magnetic-storage and switching applications have been analyzed and expressed in terms of the physical state of the material and its more fundamental properties. Current work associated with the magnetometer, the X-ray machine, and the fabrication of completely new materials is directed toward improving our understanding of the relationship between the more fundamental physical properties of magnetic materials and their chemistry. It is also directed toward the discovery and development of completely new magnetic materials.

One of the significant results of the former analysis has been the realization of an inherent limitation in the speed-power relationship which is available in toroidal samples. This limitation

has led to the study of thin films of magnetic metals where the geometry of the material would be favorable to a different kind of flux-reversal mechanism. This study is reported in 2., below.

Meanwhile, ceramic facilities have been developed for the study of problems associated with production control. Memory cores have been produced for the Memory Test Computer, TX-0 (524,228 cores), and Whirlwind I (WWI core-memory storage capacity was doubled during this quarter). Small cores (30-mil ID, 50-mil OD) for a special program counter and for a new 64 × 64 × 37-bit transistor-driven core memory for TX-0 have also been supplied, and a semi-automatic tester for these small cores has been designed and built.

2. Thin-Film Study

A random-access memory element is needed that has substantially faster switching characteristics than the present ferrite cores. Analysis of engineering parameters of magnetic materials has indicated that the figure of merit for switching speed would be improved by a factor of 100 to 1000 in a material in which flux reversal takes place by simultaneous rotation of entire domains, rather than by the creation or growth of domains of reverse magnetization (as in ferrite cores).

Evaporated metallic films, about 1000 Å thick, are being studied and have been found to reverse their flux by both domain-wall motion* and domain rotation. Magnetic films were prepared by vacuum-evaporating 80-20 Permalloy onto a heated glass substrate in the presence of an external magnetic field applied in the plane of the film. Under such conditions, the film develops a preferred magnetic axis in the field direction, becoming a single domain oriented in this direction. If the uniaxial anisotropy energy in the plane of the film is described by $E_k = K \sin^2 \Theta$, where K is a constant of the material and Θ is the angle the magnetization makes with the unique axis, then simple theory predicts, for the rotational hysteresis loops in the easy and hard (90° to easy) directions, complete irreversibility, respectively (Fig. 63-1).

The coercive force in the easy direction is $2K/M_s$, and the field required for saturation in the hard direction is also $2K/M_s$.

Experimentally, we find that the low-frequency hysteresis loops appear as in Fig. 63-2. We interpret these loops by assigning the value $2K/M_s$ to the field required for saturation in the hard direction and assume that 180° flux reversal can take place by wall motion at fields less than the $2K/M_s$ required for a rotational switch.

Thus, an experiment designed to observe fast rotational switching in the easy direction must provide a drive pulse which has a rise time that is fast, compared to the time required for walls to form and move, and a magnitude not only greater than the low-frequency coercive force, but greater than $2K/M_s$.

In the experiments we have performed, the drive pulse has a rise time of 1.0 mμsec and is generated by discharging a coaxial line through a mercury relay. To provide for an H-field with plane geometry, the pulse is sent down a strip transmission line which is terminated to avoid reflections. A pulse to reset the film after reversal by the fast-rise-time drive pulse is provided

*A magnetic system in the form of a thin film was proposed by Blois.[1] However, the switching time was not appreciably less than that for ferrites. We have interpreted this condition to mean that the switching observed by Blois was due to wall motion.

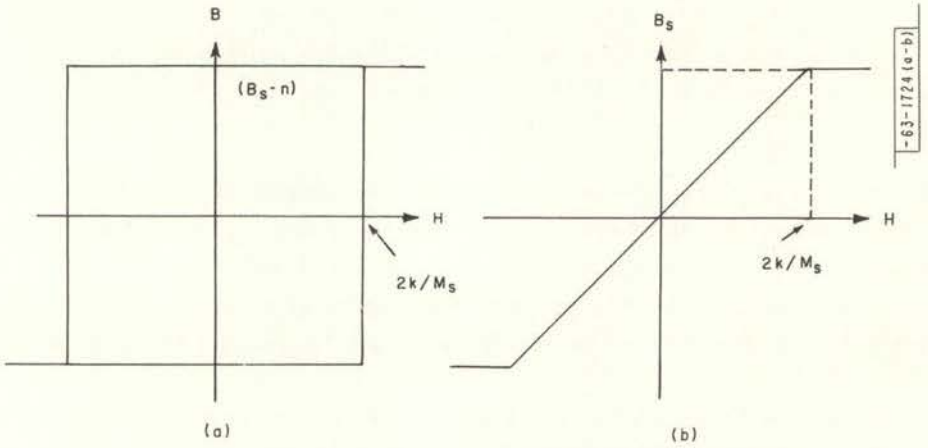


Fig. 63-1. Rotational hysteresis loops of magnetic films predicted from $E_k = K \sin^2\theta$. (a) Applied field H parallel to easy magnetization axis. (b) Applied field H perpendicular to easy magnetization axis.

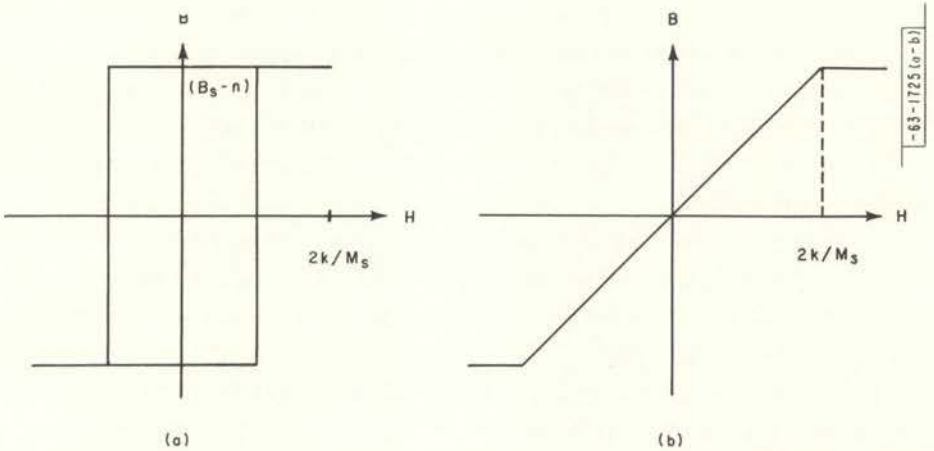


Fig. 63-2. Experimental low-frequency hysteresis loops. (a) Applied field H parallel to easy magnetization axis. (b) Applied field H perpendicular to easy magnetization axis.

by capacitor discharge through a second mercury relay. The pickup loop is balanced to eliminate air coupling as shown in Fig. 63-3; the arms of the loop are made of resistance wire to reduce circulating currents induced by the drive field; the film is placed in one arm of the loop.

To establish the time scale for rotational processes, we first place the easy axis of the film perpendicular to the drive field. The drive pulse and pickup-loop pulses are shown schematically in Fig. 63-4. Since the flux changes are reversible, film pulses at both the beginning and end of the drive pulse are in accord with the hysteresis loop in the hard direction as shown in Fig. 63-1. The long duration of the output film pulse with respect to the rise time of the drive pulse is due to the bandwidth limitation of the scope used to observe the film pulse. The conclusion is that the rotational process will follow drive pulses with rise times at least as short as 20 mμsec.

The next step is to see if irreversible switching on the same time scale can be obtained. This should appear where the easy axis is parallel to the drive field; an irreversible flux change would be characterized by the absence of the second film pulse shown in Fig. 63-4. Also, there should be a threshold field below which there is no irreversible switching. These anticipated results are obtained experimentally, although additional complicating features appear which must be further studied. The most noticeable deviation from the simple model given above is that for drive fields which are greater than the critical field. Not only the speed of switching, but also the total amount of flux which is switching, depends on the field. Thus, it appears that there is an interplay between domain and rotational processes.

Very significant results can be obtained by simultaneously applying fields parallel and perpendicular to the easy axis. Physically, we can see that a perpendicular field will lower the coercive force in the easy direction, since part of the required torque for rotation has already been supplied by the perpendicular field. The consequence of various combinations of crossed fields can easily be calculated. Experiments are planned to correlate their effects.

Equipment and instruments necessary to carry on the research program on thin films are being obtained. The vacuum and associated equipment required to deposit reproducible thin metallic films has been delivered and is being debugged. Instruments for measuring hysteresis loops, anisotropy constant, and switching speeds are in operation. New methods of sensing the film pulses are being developed which should also open up the possibility of studying, to several thousand megacycles, the sine-wave response in the hard direction. The initial permeability in this direction is of the order of 10,000 and remains high, well into the kilomegacycle range.

Studies of domain walls by the colloidal-magnetite technique have been started, and in interferometer for measuring film thickness has been set up.

Films are also being made for Group 35. G. Heller and P. Tannenwald of that group have begun an investigation of the microwave properties and uses of magnetic films.

The following will be required during the future progress of the thin film study:

(a) better experimental setups to observe and study the output voltage pulses from fast-switching films (a new Edgerton, Germeshausen & Grier scope, capable of a 2000-megacycle bandpass, has just arrived)

(b) a study of the nature of the domain walls in thin films and how to get rid of them (the walls in thin films are apparently quite different from those in bulk material)

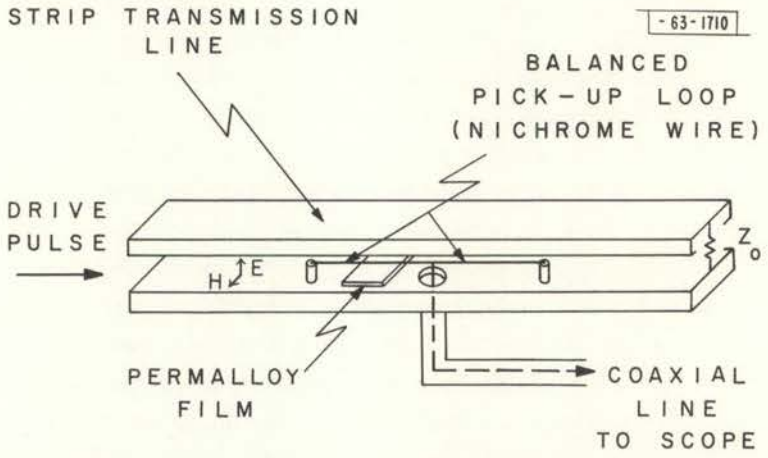


Fig. 63-3. Schematic representation of equipment used in switching experiments.

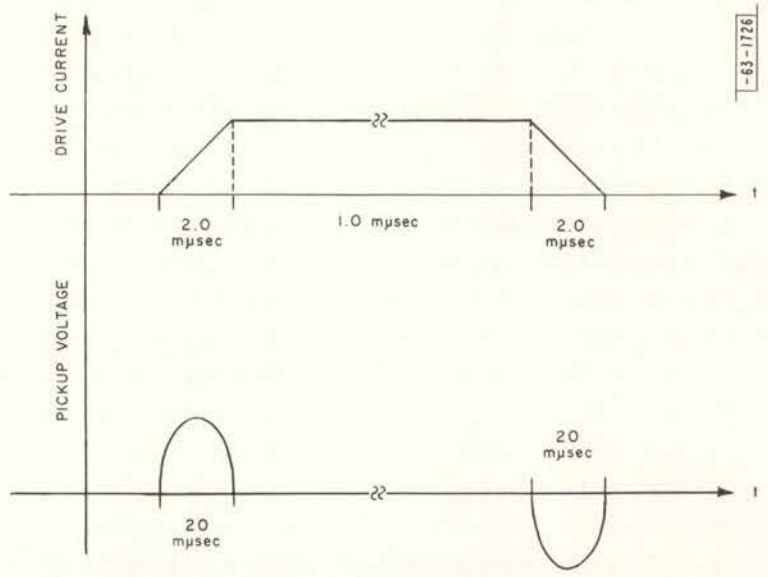


Fig. 63-4. Experiment designed to establish the time scale for rotational processes (easy magnetic axis perpendicular to drive field).

(c) a study of the factors which determine the anisotropy constant, K, within the plane of the film so that this quantity can be controlled (it determines the power the device will require)

(d) control of the evaporation procedures so that uniformity and reproducibility can be accomplished

(e) development of engineering schemes which can use the potential of the device

(f) development of fabrication and testing techniques.

It is hoped to initiate work in all of these areas more or less simultaneously during the next two quarters.

3. Inorganic Chemistry and Crystallography

a. The System $Ge^{++++}Co_2^{++}O_4 - ZnMn_2^{+++}O_4$

A significant magnetic moment was observed for the composition, $Zn_{1/2}^{++}Ge_{1/2}^{++++}(Co^{++}Mn^{+++})O_4$. This discovery stimulated an investigation of a series of compositions in the solid solution range between pure $ZnMn_2O_4$ (a tetragonal spinel) and $GeCo_2O_4$ (a cubic spinel). The crystallographic effects of varying the Mn^{+++} content were also interesting. The tetragonal distortion exhibited by several spinel-type oxides containing manganese may be caused by the presence of Mn^{+++} ions which occupy octahedral sites. A series of compositions has been prepared, their purity established, and they are now being studied crystallographically. Compositions containing up to 65 per cent $ZnMn_2O_4$ crystallize with cubic symmetry, those containing over 75 per cent with tetragonal symmetry.

b. The System $Ge^{++++}Mn_2^{++}O_2 - ZnMn_2^{+++}O_4$

Although pure $Ge^{++++}Mn_2^{++}O_4$ has not been prepared, a certain range of solid solutions with $ZnMn_2O_4$ has been found to exist and, crystallographically, this system is quite similar to the system containing cobalt described above.

c. The System $Li_x^{+}Ni_{1-2x}^{++}Ni_x^{+++}O$

Considerable effort has been required to show that a complete range of values for x is possible. For values of x between 0 and 0.33, the material crystallizes with the rock-salt structure; the size of the unit cell decreases slightly with increasing Ni^{+++} content. Thus, possible magnetic interactions between Ni^{++} and Ni^{+++} ions on the octahedral sites of the rock-salt crystal lattice can be investigated. For values of x greater than 0.33, a change in crystal structure is observed, and for x = 0.4 a magnetic moment has been measured.

d. Chemical Analysis

Memory core compositions, taken before and after the required refiring process and submitted to rigorous chemical analysis, have shown no measurable chemical difference. In both cases, the ratio $M^{++} : (M^{++} + M^{+++})$ has been found equal to 0.33, the theoretical value for a perfect spinel.

e. Rare-Earth Ferrites

Lanthanum nickel oxide, $LaNiO_3$, containing trivalent nickel was prepared and its structure determined by X-ray analysis. It has been tentatively indexed as a rhombohedrally distorted,

perovskite structure similar to $LaCoO_3$, with $a_o = 3.838 \pm 0.002$Å, $\alpha = 90°43' \pm 1'$. Samarium, gadolinium, and yttrium oxides do not react with nickel (II) oxide under the conditions used to prepare $LaNiO_3$. Neodymium oxide apparently reacts with nickel (II) oxide to form a compound possessing a complex structure.

As a result of calculations obtained by use of the Goldschmidt radii, it is theoretically possible for rhodium to form perovskite structure with the rare-earth oxides. In the presence of sodium carbonate, which acts as a flux, rhodium oxide and lanthanum oxide form a compound that has been tentatively assigned the perovskite structure which possesses a unit-cell size of 3.95 ± 0.01Å. Neodymium oxide and samarium oxide appear to react with rhodium oxide in a more complex fashion. In addition, lanthanum, praseodymium, and neodymium iron oxides have been prepared and possess slightly distorted perovskite structures: The unit-cell size of $LaFeO_3$ was found to be 3.90 ± 0.01Å; of $PrFeO_3$ and $NdFeO_3$, 3.87 ± 0.01Å and 3.85 ± 0.01Å, respectively.

4. Vibrating-Coil Magnetometer

The vibrating-coil magnetometer (VCM) has been in marginal operation during most of the past quarter. Magnetization measurements were made on a number of powder samples. New single and double coils, and a set of tapered pole caps used with the VCM have improved its response and increased its flexibility. A new magnetostriction sample-holding unit has been designed, as well as a system for low temperature measurements.

Magnetostriction measurements have been made of a single crystal of $MnOFe_2O_3$. The magnetostrictive constants obtained were $\lambda_{100} = -35 \times 10^{-6}$ and $\lambda_{111} = -2 \times 10^{-6}$. Values given by Bozorth et al,[2] for a material of similar composition are $\lambda_{100} = -35 \times 10^{-6}$ and $\lambda_{111} = -1 \times 10^{-6}$.

J. B. Goodenough, D. L. Brown, W. J. Croft, C. O. Dugger, Elaine Keith, F. S. Maddocks, N. Menyuk, R. A. Pacl, D. O. Smith, G. Weiss, D. G. Wickham, A. Wold, R. C. Zopatti

C. TRANSISTORS

Transistors, because of their low power requirements, small size, and greater reliability are being developed and evaluated for use in place of vacuum tubes in computer circuits. Studies are being conducted to determine the fundamental principles of operation and to find a correlation between these principles and the known, measurable parameters of transistors. A special study has been made of the switching behavior and related hole storage of Philco surface-barrier transistors (SBT's). Life tests continue on SBT's in several types of operating circuits. Philco has in pilot-line production a new microalloyed transistor (MAT), type L-5134, which is being evaluated for circuits that must supply high currents.

1. Transistor Switching Study

A study has been made of the theory of transistors with respect to their application to the high-speed switching circuits used in digital computers.[3] As a result of this study, briefly accounted below, it is possible to choose several independent, comparatively easy to measure, sets of parameters, instead of the difficult measurements of forward and inverse cutoff frequencies. The details of this study are being published in 6M-4581.

Nearly two years ago, Ebers and Moll[4] introduced four transistor parameters which can theoretically be used to describe completely the rise, fall, and delay (storage) times of transistors:

α_n, α_i = normal and inverse grounded-base current gains

ω_n, ω_i = normal and inverse grounded-base frequency cutoffs

An expression, in terms of the above parameters, had previously been derived by Shockley[5] for a one-dimensional transistor model. This expression has the form

$$\alpha_n = \alpha_i = \alpha_o = \frac{1}{1 + 1/2(w/L_b)^2} \quad \text{and} \tag{1}$$

$$\omega_n = \omega_i = \omega_{c\alpha} = \frac{2D_p}{w^2}\left[1 + 1/2\left(\frac{w}{L_b}\right)^2\right] \tag{2}$$

where

p = the minority carriers in the base region

D_p = the diffusion constant of the minority carriers in the base region

w = base width

L_b = the diffusion length

However, in practice, it is found that these parameters have different values in the forward and inverse transistor configurations. In fact,

$$\omega_n > \omega_i \quad \text{and} \quad \alpha_n > \alpha_i \quad .$$

Therefore, the conclusion was drawn that the effective inverse base width, w_i, is greater than the normal base width, w_n.

Assuming

that the emitter efficiency, γ, = 1,

that the effective base lifetime of the minority carriers, τ_b, is independent of transistor configurations, i.e.,

$$\tau_{b_n} = \tau_{b_i} = \tau_b = \frac{L_b^2}{D_p} \quad , \quad \text{and}$$

that $\frac{w_i}{L_b}$ and $\frac{w_n}{L_b}$ are both < 1,

the following equations can be written:

$$\alpha_n = \frac{1}{1 + 1/2(w_n/L_b)^2} \tag{3}$$

$$\alpha_i = \frac{1}{1 + 1/2(w_i/L_b)^2} \tag{4}$$

$$\omega_n = \frac{2D_p}{(w_n)^2} \left[1 + 1/2(w_n/L_b)^2 \right] \tag{5}$$

$$\omega_i = \frac{2D_p}{(w_i)^2} \left[1 + 1/2(w_i/L_b)^2 \right] \tag{6}$$

and the grounded-emitter current gain, β, can be expressed

$$\beta_{n,i} = \frac{\alpha_{n,i}}{1 - \alpha_{n,i}} = 2\left(\frac{L_b}{w_{n,i}}\right)^2 = \frac{2D_p}{(w_{n,i})^2} \tau_b \tag{7}$$

Since the storage coefficient, τ_s, can be expressed

$$\tau_s = \frac{w_n + w_i}{w_n w_i (1 - \alpha_n \alpha_i)} = \tau_b \tag{8}$$

then

$$\beta_{n,i} = \frac{2D_p}{(w_{n,i})^2} \tau_s = \alpha_{n,i} \omega_{n,i} \tau_s \tag{9}$$

or

$$\beta_{n,i} + 1 = \omega_{n,i} \tau_s \tag{10}$$

The relation between storage coefficient, current gain, and frequency response is plotted in Fig. 63-5 for a transistor which meets the foregoing assumptions.

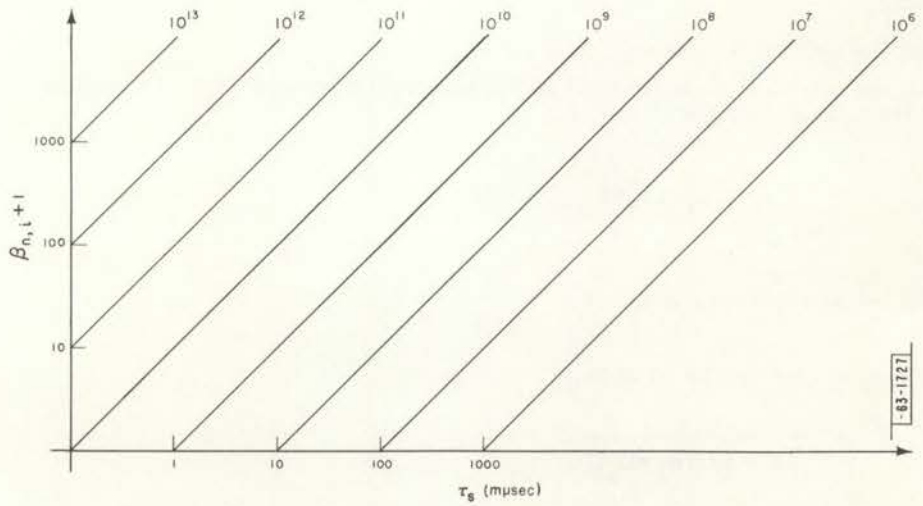


Fig. 63-5. Relation between storage coefficient, current gain, and frequency response.

Since, as shown by Ebers and Moll, the switching response of a transistor may be given by the relation

$$t = \tau \ln[F(\alpha, I_e, I_b, I_c)] \tag{11}$$

where $F(\alpha, I_e, I_b, I_c)$ is a function of the circuit conditions, the common-base short-circuit current gain, and the configuration, mode, and region of operation, the log term depends on circuit properties determined by the value of τ and can be expressed by the following table:

TRANSISTOR CONFIGURATION	τ
Common-base rise time (active)	n: $\frac{1}{\omega_n}$ i: $\frac{1}{\omega_i}$
Common-emitter or collector rise time (active)	n: $\frac{1}{\omega_n(1-\alpha_n)}$ i: $\frac{1}{\omega_i}\frac{1}{(1-\alpha_i)}$
Storage time	$\frac{\omega_n + \omega_i}{\omega_n\omega_i(1-\alpha_n\alpha_i)}$

It can be shown that

$$\tau_s = \frac{\omega_n + \omega_i}{\omega_n\omega_i(1-\alpha_n\alpha_i)} = \tau_b \tag{12}$$

and that

$$\frac{1}{\omega_n(1-\alpha_n)} = \frac{1}{\omega_i(1-\alpha_i)} = \tau_b = \tau_s \tag{13}$$

Therefore, τ_s is a measure of storage and is of interest in saturating circuits. However, it is also an approximate measure of the common-emitter and collector switching times and is thus of interest in nonsaturating circuits as well.

In conclusion, it is possible to choose, from the relation shown in Eq.(10), several independent sets of parameters to specify the switching transistor – β_n, β_i, and τ_s, which are relatively easy to measure.

2. Micro-Alloyed Transistors

Measurements were made on 60 samples of the Philco L-5131 micro-alloyed transistors (MAT), and τ_s (storage coefficients) ranged from 40 to 400 mμsecs. They were then grouped according to τ_s ($\tau_s < 100$, $100 < \tau_s < 200$, and $\tau_s > 200$ mμsec), and re-examined carefully. The transistors with high τ_s had good micro-alloyed collectors as evidenced by

(a) high inverse grounded-emitter current gain, β_i, out to 50 ma

(b) low saturation drop, and

(c) close adherence to the relation $\beta_i + 1 = \omega_i \tau_s$ which depends upon $\gamma_c = 1$ (see Eq. (10), page 36).

The low τ_s units did not exhibit any of these properties, and it was assumed that these units did not have micro-alloyed collectors. All units had good emitters.

Low values of τ_s are desirable to make the transistor usable as a fast switch, and an alloyed collector is desirable to reduce the problems of solution cavities prevalent at high power levels in the SBT. A suggestion was made that Philco make a new unit with an alloyed, but noninjecting collector. They had been investigating this type structure on their own for other reasons and had the technique available.[6]

The MAT L-5134 is the result and has the gain of the L-5131 in the forward direction but a storage factor, τ_s, of less than 130 mμsecs. The L-5134 will be used in those circuits required to supply high currents, particularly the output circuits of flip-flops, register drivers, and cascode circuits. This transistor is presently available in limited quantities from pilot lines, but it is expected that it and other similar units will be brought into regular production soon.

3. Transistor Life Tests

The following table summarizes SBT life tests to 31 August 1956:

Test	No. of Transistors	Operating Time	Transistor Hours	Failures
FF 1 and 2	8	15,425		
FF 3 through 6	16	14,630	416,691	2
Control for above	9	6,579		
Shelf Life	14	11,274	175,086	2
Direct-coupled shift-reg.	16	11,797	188,752	0
R-C coupled shift-reg.	16	11,743	187,888	1
Diode-coupled shift-reg.	16	10,838	173,408	0
Shielded shift-reg.	99	12,090	1,196,910	0
Unshielded shift-reg.	99	10,746	1,063,854	0
Single-rank shift-reg.	149	6,449	960,901	0
TM-1 (multiplier)	664	9,000	5,976,000	1
Total	1,106		10,339,490	6

The six failures, in an average time of 9,350 hours, represent a failure rate of 0.06 per cent per 1000 hours.

The shielded 8-digit shift register has been operating continually for 10,784 hours without loss of pattern. The unshielded unit has averaged 2000 to 3000 hours between errors, but there is no way of knowing whether this is due to lack of shielding. The single-rank register lost its pattern after 5,932 hours due to an open circuit in the printed wiring. The TM-1 multiplier has run as long as 35 days without error.

D. J. Eckl
C. T. Kirk, Jr.
Patricia Fergus

D. MEMORY

1. Transistor-Driven Core Memory for TX-2

A 64 × 64 × 37 random-access memory, using 50-mil OD and 30-mil ID cores, is being built for the TX-2 computer. The use of transistors in place of vacuum tubes in the sensing, selecting, and inhibiting circuits is expected to improve reliability, reduce power requirements and heat dissipation, and somewhat shorten cycle time. Circuits are being designed for the use of transistors in the memory address circuitry and the digit-plane drivers. The problem of switching the large currents normally required in memory-driving circuits has been solved with a Western Electric GA-52830 transistor driven by a General Electric 2N123 transistor, which in turn is driven by a "cascode" circuit consisting of one Philco surface-barrier transistor (SBT) and two Philco surface-alloy transistors (SAT) as shown in Fig. 63-6.

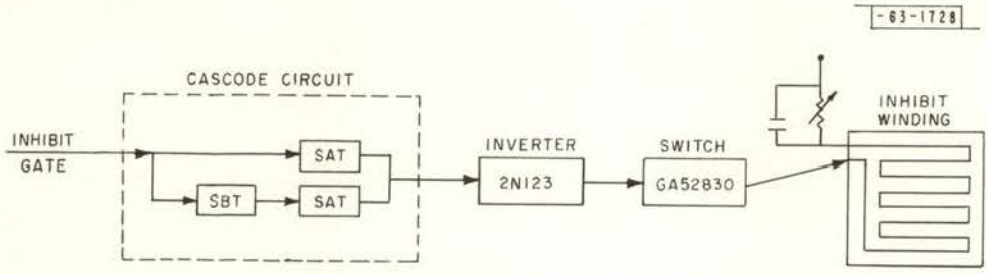


Fig. 63-6. Digit-plane driver – block diagram.

2. Tape Drive for TX-2

A tape system is being designed which is expected to eliminate the mechanical complications and, therefore, much of the extensive maintenance required by most commercially available computer tape drives. Two 3-phase induction motors will drive the tape reels, and there will be no other moving parts. Power to each motor will be controlled by a 3-phase magnetic amplifier driven by transistors. In the search mode, the tape can be driven very fast in either direction while the driving motor approaches its synchronous speed of 1800 rpm.

The basis of the plan is a method of recording which will allow reading over a wide range of tape speeds. For a ONE, the output signal is of one polarity, and for ZERO, of the opposite polarity. All that is needed in the sense amplifier is enough gain to operate at the slowest speed desirable. Normal reading and writing will be at a controlled intermediate speed. Two methods of accomplishing this are being evaluated:

(a) prerecord a signal of constant density on one track and use it to control the motor speed as well as frequency of recording, and

(b) continuously record and read (with two heads on the same track) a signal of constant frequency; the shape of the signal picked up by the read head would be an indication of tape speed.

The large internal memory of TX-2 makes it possible to transfer relatively large blocks of information at a time, making short start and stop times less necessary. Reading, writing, and high-speed searching can be done in either direction.

3. 256^2 Memory

Twenty of the 38 planes for the 256 × 256 × 38 memory had been assembled in the memory stack by the end of August and adjustments were nearly completed. It is expected that the stack will be operating in September.

Two methods were considered for the interconnection of the sense windings, which for these planes are broken up into four sections, each consisting of four 64 × 64 modules and each of which feeds one of the four sense-amplifier inputs. It was decided to connect two modules in series, in parallel with the other two modules which were also connected in series. This method of interconnecting was chosen because

(a) the delay time from one end to the other of the sense winding is somewhat shorter than that with other methods

(b) the reduction in over-all noise with this method is great enough to more than compensate for the resultant reduction in the amplitude of the signal.

4. Memory Planes Using Printed Circuits

Sample 4 × 4 memory planes were constructed using printed circuits to link the cores together instead of the conventional wiring (see Quarterly Progress Report, 15 March 1956). Experiments conducted demonstrated the worth of this technique and when the special photographic mask is obtained, it is hoped that working 4 × 4 printed planes can be made with no soldered joints. Three-dimensional, photo-printing planar masks are being made by an outside vendor for the simultaneous printing of four conductors through each of 4,096 cores in one operation. Delivery of these masks is expected in September.

Other methods of printing circuits are also being investigated and evaluated with the help of the General Engineering Section of Group 60.

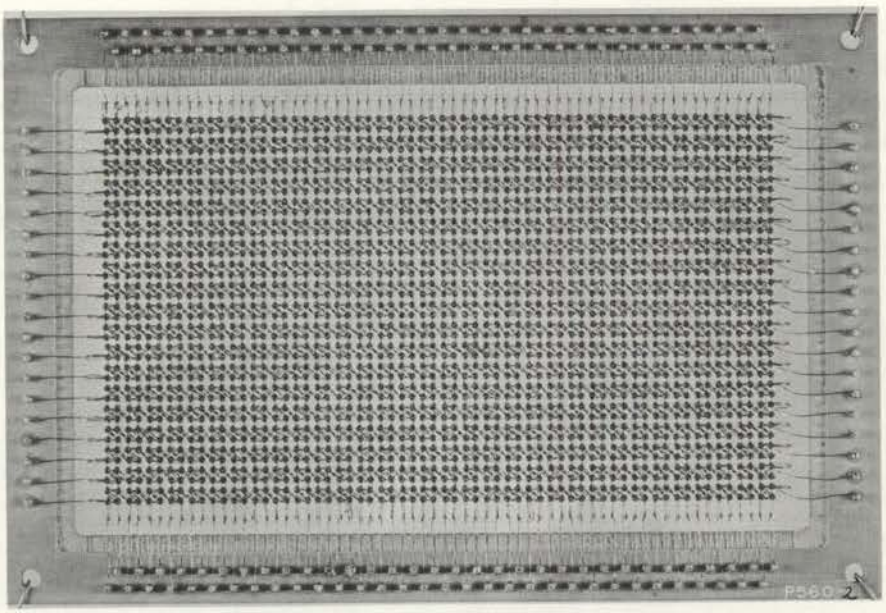


Fig. 63-7. Single-plane, 64 × 38 index memory for TX-2.

5. Printed Circuits for Memory Planes Using Evaporated Magnetic Films

The processes developed during the investigation of printed-circuit memory planes, using cores as the memory element, are being applied to the preparation of samples of memory planes using evaporated metallic films as the memory element. Preparations are being made to construct a 16 × 16 memory plane.

6. Index Memory for TX-2

A 64 × 38 memory has been designed and is being built to provide index registers and program counters for TX-2 (Fig. 63-7). This single-plane, random-access memory will store 64 words, 19 bits long. Two cores per bit are used for register selection instead of the usual 2-coordinate selection. Because the cores have a low coercive force, and therefore a relatively slow switching speed, during the read operation they are driven with a current many times their coercive force so that they switch in 0.025 μsec. A 3:1 selection ratio is used during the write operation and the write time is therefore somewhat slower – 2.5 μsecs. Information is read out within 1.0 μsec after the respective address is fed into the memory.

J. L. Mitchell G. A. Davidson
R. L. Best D. H. Ellis
S. Bradspies E. A. Guditz

E. SYSTEM DESIGN

The system design section designs, builds, and installs the electronic equipment for TX-0 and TX-2, the high-speed experimental computers being developed at Lincoln Laboratory.

1. TX-0

TX-0 has been built and put into operation over the past six months. TX-0 is an experimental computer designed to minimize the amount of time and skilled labor necessary to assemble it. The extensive use of transistors is expected to substantially increase reliability and decrease operating power requirements. (See Fig. 63-8.)

The frame for TX-0 was erected on 17 March 1956. All back-panel wiring and plug-in units were installed by 1 April, and the central machine (arithmetic section) was operating by 15 April. The high-speed circuitry in the central machine uses about 2600 Philco L-5122 surface barrier transistors; no diodes or vacuum tubes are used in this part of the machine. Fig. 63-9 is a system diagram of TX-0.

Eighteen registers of toggle-switch storage are provided in TX-0. One magnetic core is used per register; the cores are driven by Western Electric GA-52830 transistors. The design for this toggle-switch storage is described in a master's thesis, "A Magnetic-Core Test Storage," by John N. Ackley, M.I.T.

a. TX-0 Circuitry

The high-speed circuitry[7] for TX-0 uses Philco L-5122 SBT's. The logical circuitry for the central machine consists of small plug-in units, each containing one, two, or three transistors with their associated registers and capacitors. The types of units and their functions are schematically represented in Fig. 63-10. AND and OR gates are formed from inverter or

GROUP 63

A Operating console
B Photoelectric tape-reader input
C Flexowriter input and output
D Plug-in units
E 256^2 core memory

Fig. 63-8. TX-0 computer.

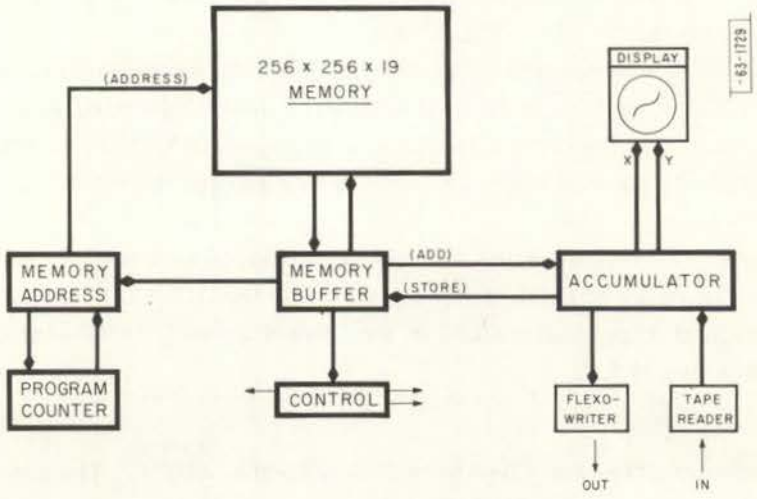
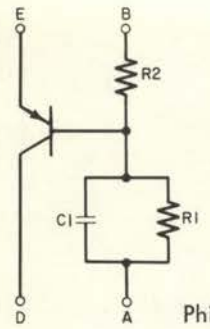


Fig. 63-9. System diagram of TX-0.

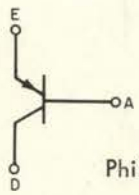


TYPE	R1	C1	R2	USE
P	2.7 K	22μμf	56 K	pulse input gate
L	2.2 K	47μμf	82 K	level input gt. & inv.
M	2.2 K	47μμf	39 K	MBR level rd-in from memory
R	1.5 K	68μμf	15 K	register driver inv.
S	3.9 K	47μμf	180 K	steering gate

Philco 5122

3-63-1730

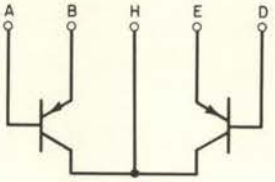
TYPE T



Philco 5122

SINGLE TRANSISTOR

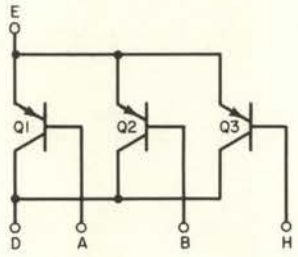
TWO E.F's



Philco 5122

TYPE E

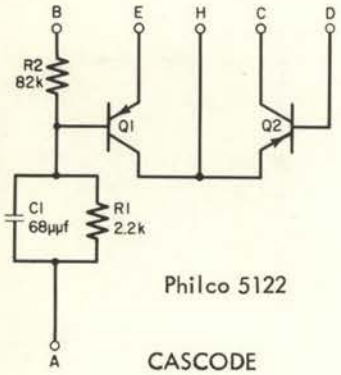
TYPE A



Philco 5122 (3)

THREE E.F's

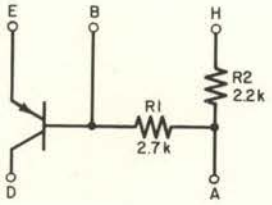
TYPE C



Philco 5122

CASCODE

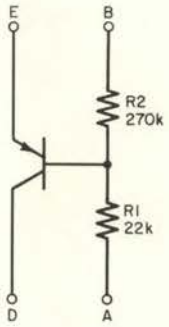
TYPE F



GE 4JD1A17

FERRANTI

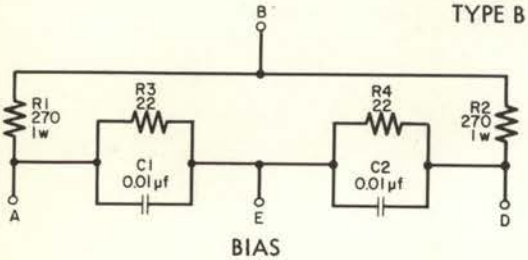
TYPE G



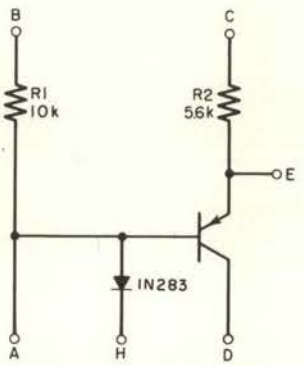
GE 4JD1A17

INDICATOR LIGHT CIRCUIT

TYPE B



BIAS

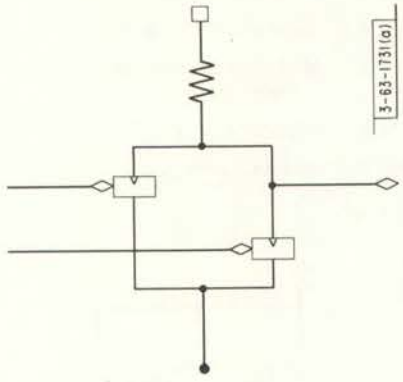


GE 4JD1A17

FII

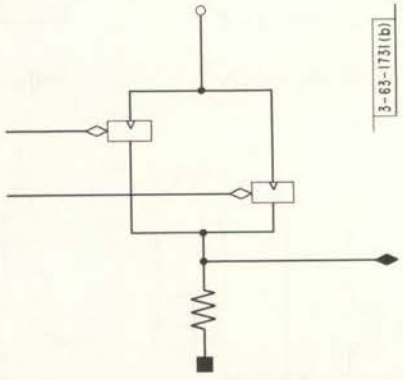
FERRANTI (Mod II)

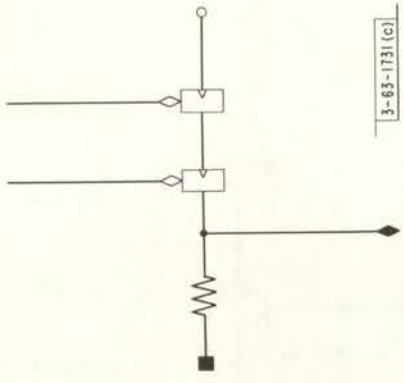
Fig. 63-10. Schematic representations of the types of plug-in units and their functions – TX-0.



(a) AND gate – for ground level in, ground level out.

(b) AND gate – for ground level in, –3 level out.





(c) Inverting OR gate – for ground level in, –3 level out.

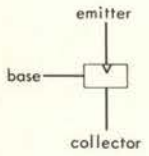
Fig. 63-11. AND and OR gating circuits – TX-0.

emitter-follower combinations. The cascode circuit is used as a power amplifier for fast rise and fall times. Timing pulses are generated by vacuum tubes and gated on and off by a register driver circuit. Marginal checking is performed by varying a positive-base bias voltage. The TX-0 high-speed flip-flop, capable of 5 mcps operation, uses ten SBT's.

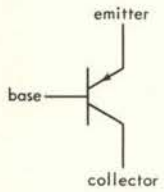
The following symbols are used in the logic and circuit schematic representations of the circuits in TX-0:

Transistors:

Logic



Circuit



Levels:

−3 volt ——●

Ground ——◇

Pulses:

Negative (ground to −3 volts) ——▸

Positive (−3 volts to ground) ——▹

Supplies:

−3 volt ●

ground ○

−10 volt ■

+10 volt □

The logic circuits of TX-0 are as follows:

(1) AND and OR gates (see Fig. 63-11).

(2) Inverter Circuit (see Fig. 63-12).

(3) Emitter-Follower Circuit – A combination of inverters and emitter followers, generally alternated, insures saturation when the emitter follower is turned on. Figure 63-13 is a plot of saturated and nonsaturated emitter followers. The emitter follower in TX-0 will provide 8 ma of output current at −3 volts and will drive a capacitive load of 120 μμf with a rise time of 0.1 μsec.

(4) Cascode Circuit – This circuit takes advantage of the fast rise time of the inverter and the fast fall time of the emitter follower. It is used as the

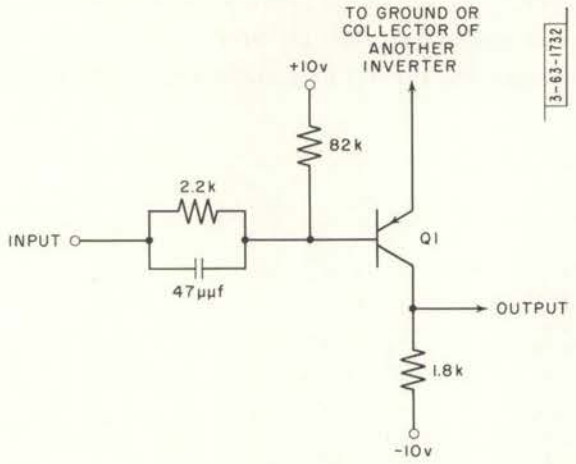


Fig. 63-12. Inverter circuit – TX-0.

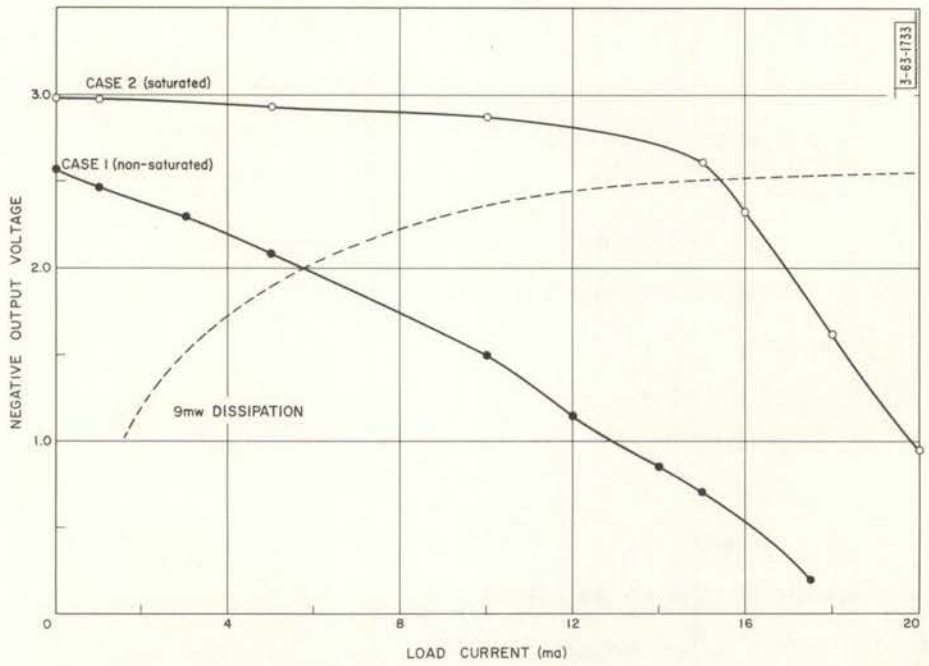
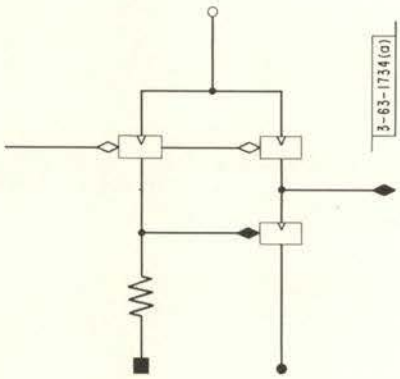
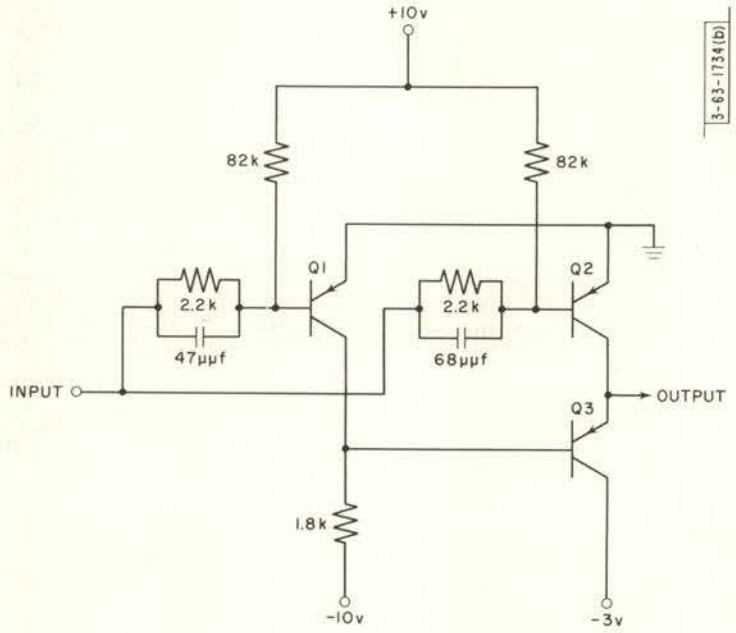


Fig. 63-13. Output voltage vs load current of TX-0 emitter – follower circuit.



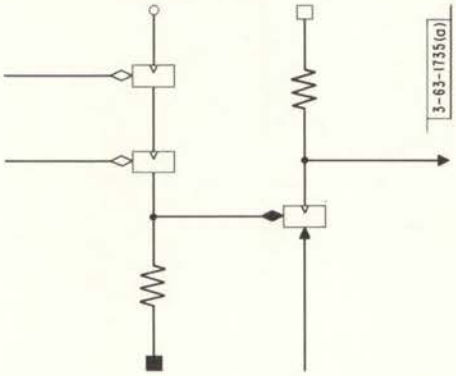
(a) Logic schematic.



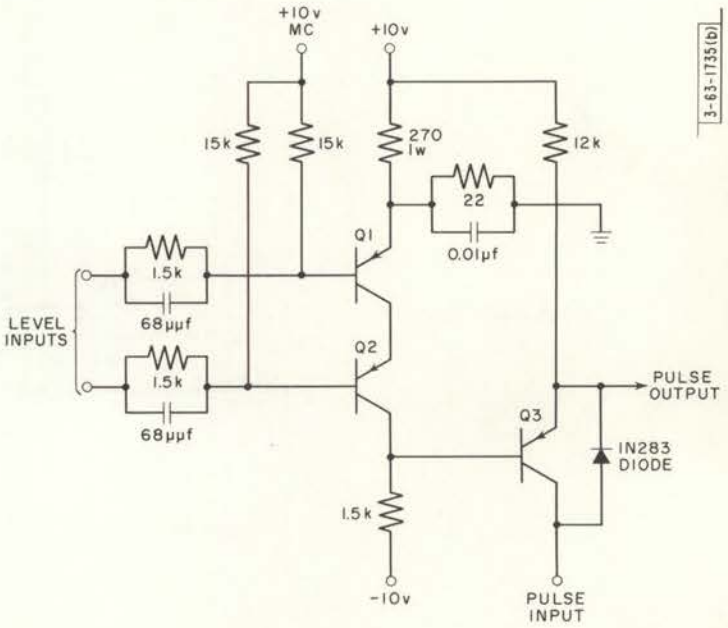
(b) Circuit schematic.

Fig. 63-14. Cascode circuit of TX-0 – for achieving fast rise and fall times.

GROUP 63

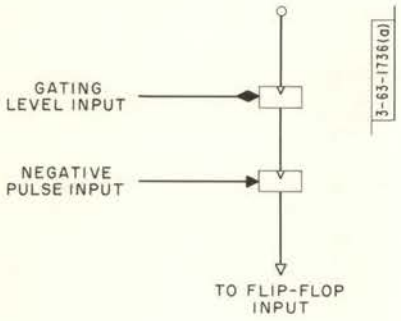


(a) Logic schematic.



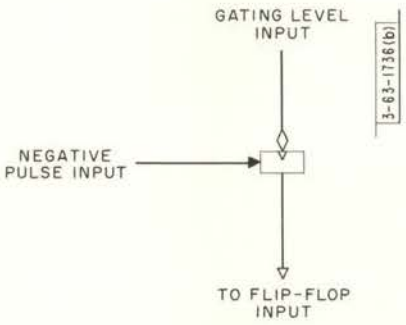
(b) Circuit schematic. Max. pulse current, 30 ma, for driving 10 pulse bases. Pulse voltage drop through register driver, < 0.5 volt.

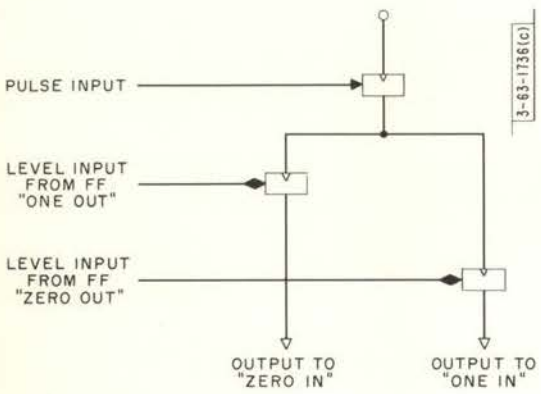
Fig. 63-15. Register driver circuit of TX-0 – for supplying 3-volt negative pulses to the input gates of the flip-flops.



(a) Circuit for inverting and gating a negative pulse using two transistors.

(b) Alternative circuit using one transistor.





(c) Circuit necessary for directing the pulse to the proper side of flip-flop for complementing when alternative circuit (b) is used.

Fig. 63-16. Pulse inputs to flip-flops – TX-0.

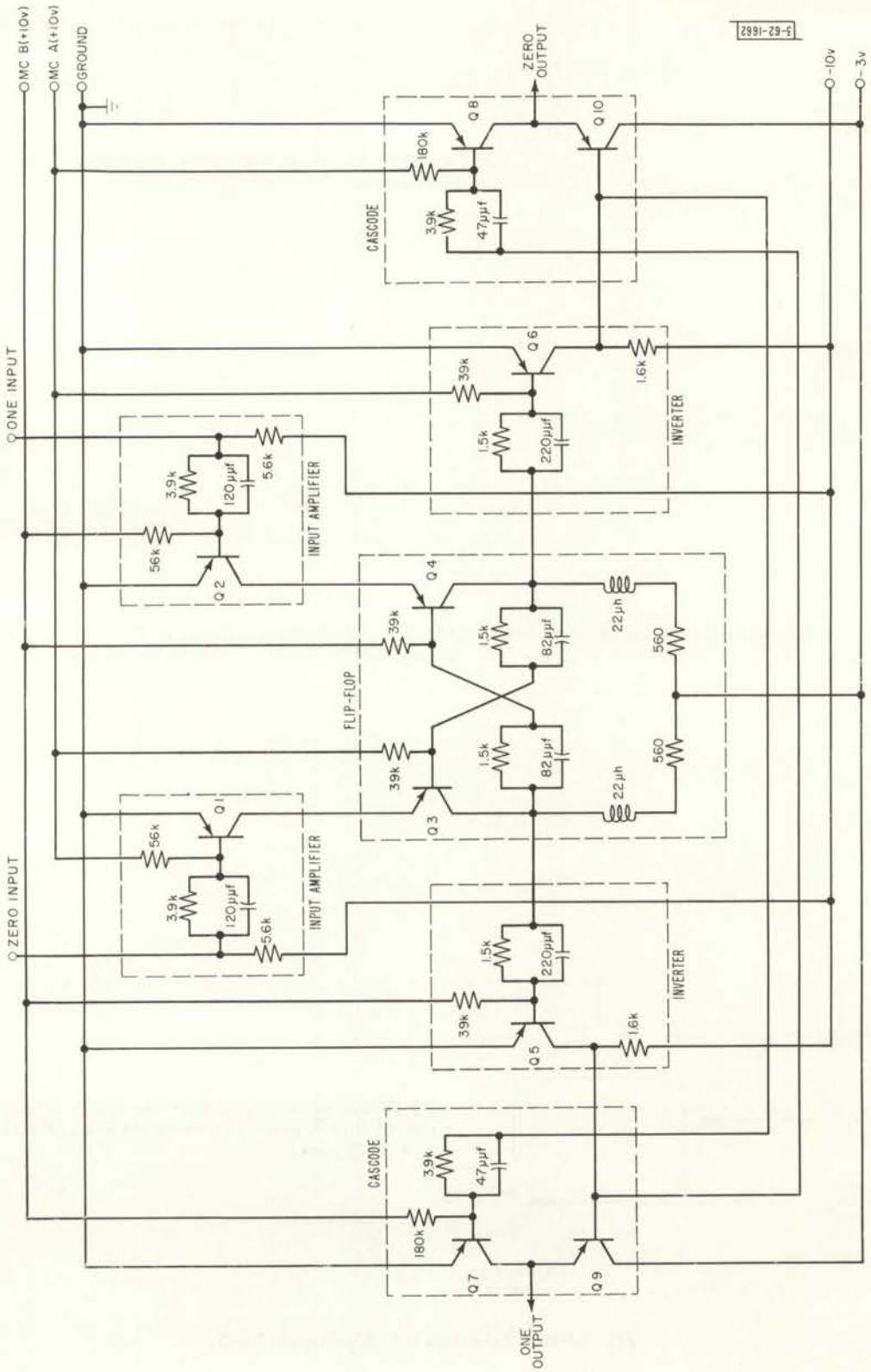


Fig. 63-17. TX-0 flip-flop schematic.

output stage of all flip-flops, as a power amplifier for driving many transistor bases, and as a cable driver when sending levels to the memory over 160-ohm coaxial cable. (See Fig. 63-14.)

The pulse circuits of TX-0 are as follows:

(1) Timing pulses – Generated by vacuum tubes, 30-volt positive pulses are sent to the computer through 93-ohm coaxial cables.

(2) Register Driver (see Fig. 63-15).

(3) Pulse Inputs to Flip-Flops (see Fig. 63-16).

The TX-0 flip-flop is schematically represented in Fig. 63-17. (See also M.I.T. Lincoln Laboratory Quarterly Progress Report, 15 March 1956.)

The details of TX-0 circuitry will be published in 6M-4561, "TX-0 Circuitry," by John R. Fadiman and, together with 6M-4571, "Transistor Logic in TX-0," by Richard C. Jeffrey (also to be published), will describe the logic and system design of the transistor circuits used in TX-0.

b. TX-0 In-Out Equipment

The in-out equipment for TX-0, in addition to the toggle-switch storage and push-button facilities, consists of a high-speed photoelectric tape reader (PETR), cathode-ray-tube display, and Flexowriters.

(1) Photoelectric Tape Reader

The tape input of TX-0 is a Ferranti high-speed PETR which has been converted from vacuum-phototube to phototransistor operation. This unit is British-made and was originally equipped with Mullard 90 AV tubes. It has been revamped and now uses eight Texas Instruments

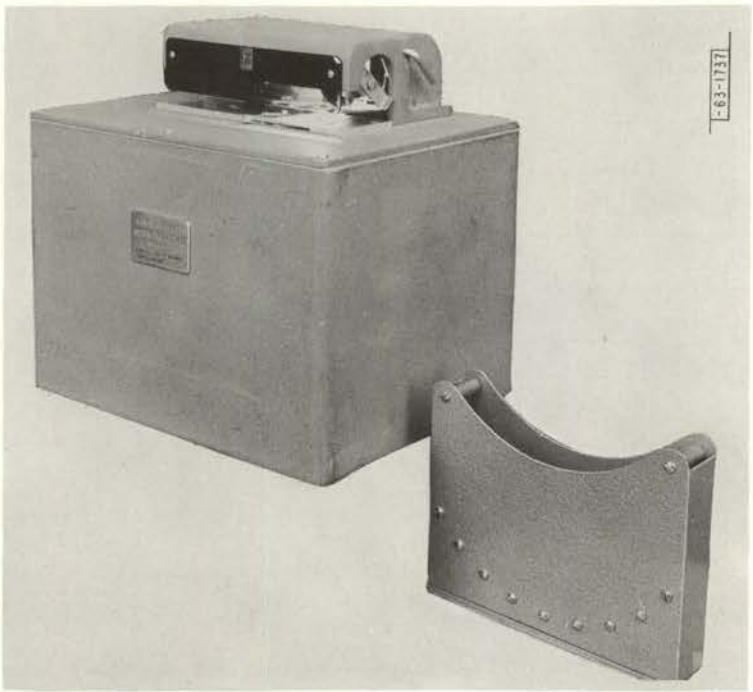


Fig. 63-18. High-speed photoelectric tape reader (PETR) – TX-0.

phototransistors, type 800. The PETR uses 1" paper tape, each line of which has seven information holes and one feed hole. The friction drive mechanism has been left unchanged and will transport 200 lines of tape per second when running free. Marginal checking has been performed on the phototransistors, and the PETR has been operating satisfactorily since June. (See Fig. 63-18.)

(2) Cathode-Ray-Tube Display

The cathode-ray tube (CRT) used in the TX-0 display is a round, 12-1/2", all-electrostatic, Dumont type K1354P2.

The display decoder is fully transistorized, and each stage consists of a constant current source and a switch; n-p-n transistors are used in a circuit similar to the familiar 3-triode, vacuum-tube decoder. To reduce base current errors, however, two transistors are used to obtain an effective gain of β^2. The switch outputs are in parallel for adding the currents which go to the deflection amplifiers.

The deflection amplifiers are, essentially, grounded-grid, high-voltage triodes, used as n-p-n devices with an alpha ratio of 1.0000. To prevent the cathode ground potential from varying excessively, a simple feedback amplifier samples the cathode-to-ground voltage of the output amplifier triode and drives its grid down to an appropriate level.

The K1354P2 CRT has a relatively good focus-deflection characteristic. However, the focus degradation at the corners of a square raster limits the density of the usable information. To correct for this defect, a special decoder and amplifier were designed. The decoder uses 20 n-p-n transistors and its output is proportional to the absolute value of the X-position plus the

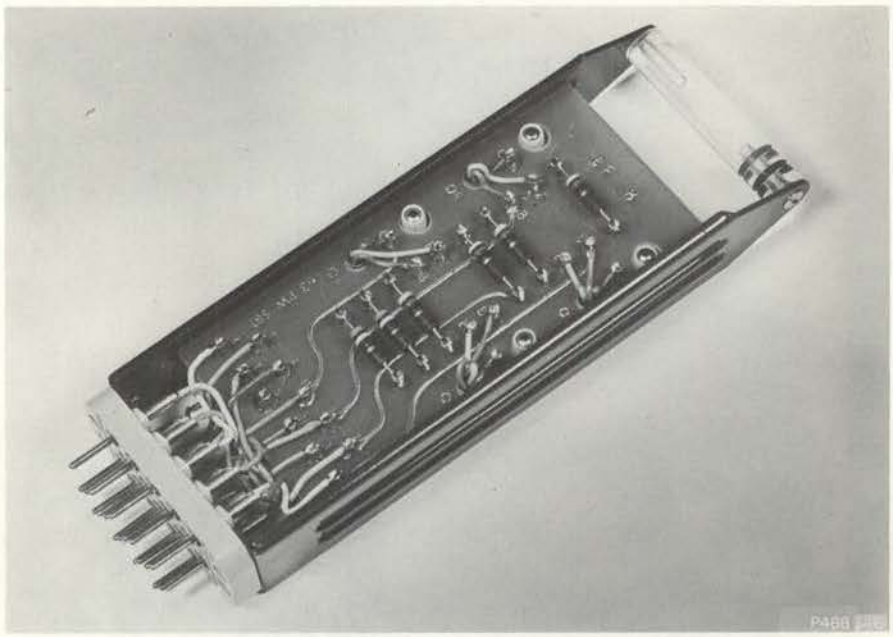


Fig. 63-19. TX-2 emitter – follower plug-in unit.

absolute value of the Y-position. This feeds a 2-tube, 3-cathode, nonlinear, feedback amplifier. The density of the information has been improved by at least a factor of two.

(3) Flexowriter

A standard Flexowriter unit is used for both input and output. In an input mode, the information can be typed on the Flexowriter directly into the live register of the computer by means of Clare mercury relays operated by the Flexoselector contacts. In an output mode, transistor amplifiers in the computer actuate Clare multipole mercury relays to type out or punch out information on paper tape.

2. TX-2

TX-0 was originally designed for expansion from an 18-bit to a full 36-bit machine. The system design section has been designing, building, and installing the additional and improved circuitry for this expansion of TX-0 to TX-2.

a. Plug-in Units for TX-2

The plug-in units of TX-2 perform the following functions:

(1) the logic circuitry for the transitor inverter and emitter-follower circuits (Fig. 63-19)

(2) pulse-gating circuitry

(3) transistor circuitry for the sense amplifiers, digit-plane driver, memory selection, and read/write driver circuits

(4) some of the transistor decoder networks for input and output equipment (Fig. 63-20)

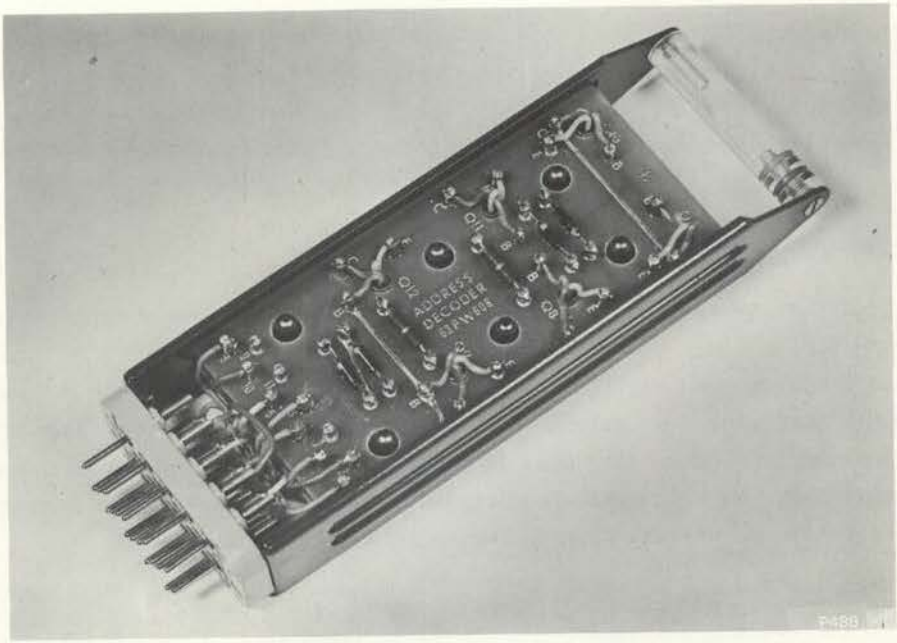


Fig. 63-20. TX-2 address decoder plug-in unit.

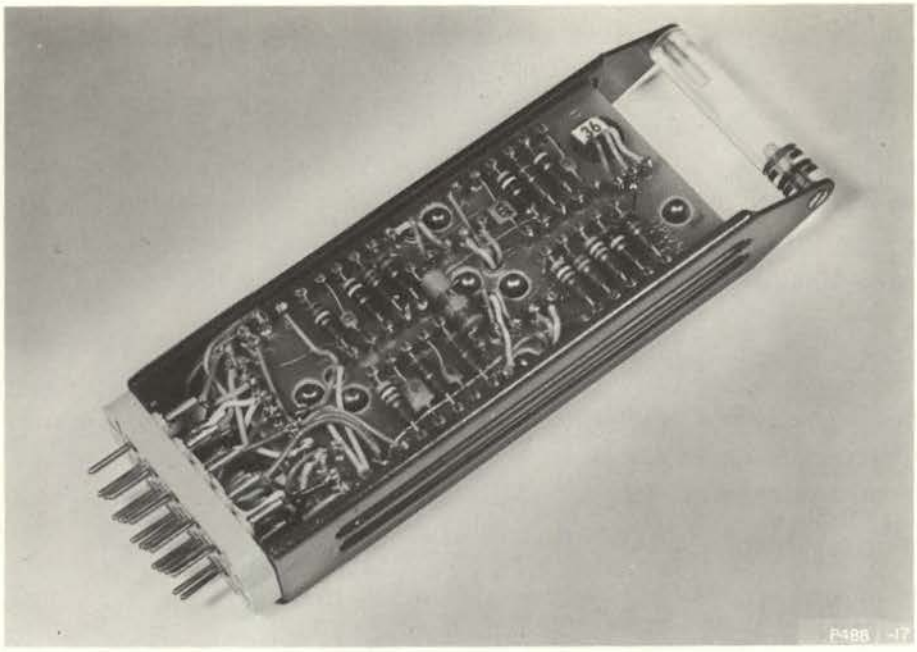


Fig. 63-21. TX-0 flip-flop plug-in unit.

(5) memory-driver circuitry for the 64 × 64 × 38 transistor-driven core memory

(6) flip-flop circuitry (Fig. 63-21).

The units consist of two etched cards, mounted back to back and fitted into the grooves in the sides of the panel frame. All components are mounted on the front side of the card for easy maintenance; the handle of the unit is notched and painted for type identification; the plug is a rugged, power-type connector. The average unit requires only about four hours to assemble.

b. Transistorized Magnetic d-c Power Supplies for TX-2

The regulated d-c power supplies used in TX-2 employ a self-saturating, polyphase bridge, magnetic amplifier, and high-power silicon rectifiers for the d-c power stage, and are driven by a transistorized push-pull regulating circuit. A large output capacitance is used for filtering and stability, and a mercury battery or silicon diode is used as a reference voltage. Regulation is approximately ±2 per cent peak-to-peak for a combination of ripple and dynamic load and line disturbances. The supplies are designed to override most utility-line transients. Figure 63-22 is a schematic representation of these d-c power supplies.

K. H. Olsen
S. T. Coffin (Group 62)
J. L. Downing
J. R. Fadiman
B. M. Gurley
W. H. Highleyman
K. Konkle
M. Petersen

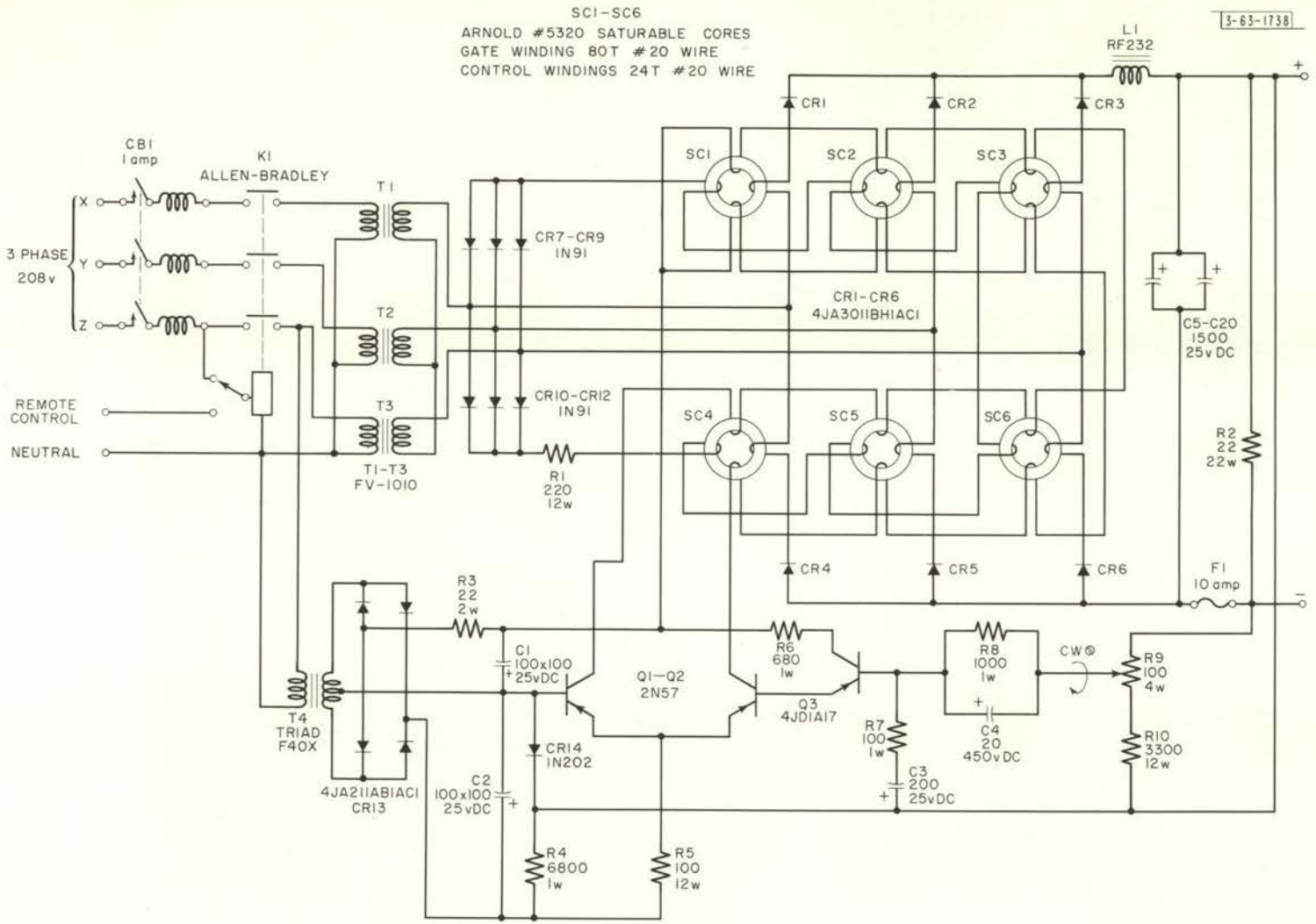


Fig. 63-22. Schematic of d-c power supply – TX-0.

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GROUP 63

F. LOGICAL DESIGN

1. Expansion of TX-0 to TX-2

TX-2, a full 36-bit computer incorporating many new developments in circuits, memories and logical organization, will be a new and important member of the Lincoln family of digital computers for the handling of real-time control and scientific problems. The original design of TX-0, an 18-bit, experimental computer, provided for its expansion to 36 bits and anticipated the improved transistor circuitry and packaging that would be incorporated as a result of the design improvement that would be made during the development of TX-2.

The 36-bits of TX-2 are organized in 9-bit subunits, which may be independently and concurrently operated under program control. The system is binary, parallel, and single-address, but because the 36-bit register and the arithmetic exchange and control element can be addressed directly by all instructions as well as indirectly by load and store instructions, much of the flexibility of a double-address code is retained without sacrificing the simplicity and directness of a single-address code.

2. Input-Output System of TX-2

TX-2 was designed to permit the simultaneous operation of several input-output devices by the use of a "multiple-sequence program technique," resulting in a computer that has several instruction sequences which share the time of the central computer. It is, thus, a number of logically separate computers which use the same memory, program, and arithmetic elements. When an input-output device needs attention, its program counter is selected and enough computer instructions from its sequence are performed to meet its current needs; control then automatically reverts to some other sequence. The main computation program sequence is treated as another "user" of the machine and is given attention only when the more pressing needs of input-output devices have been met. A priority system is used to link the sequences of input-output devices. High-speed, free-running devices such as magnetic tape units are assigned a high priority so that they will get attention first if several devices request attention at the same time. Low priority is assigned to such things as electric typewriters. Each instruction carries a break-point bit to determine whether a change in "user" is permissible. The multiple sequence approach to the input-output problem has several advantages:

(a) A number of input-output devices can be operated concurrently with a minimum of storage;

(b) Machine time is used efficiently, since no time need be lost waiting for input-output devices to complete their operations;

(c) Each input-output device may proceed at its top speed with the activities of several devices interleaved automatically without program considerations, both those of average and peak-rate limitations;

(d) Programming for input-output is flexible since routines for each device may be as long or as short as the particular situation requires.

W.A. Clark J.M. Frankovich
B.G. Farley H.P. Peterson
J.W. Forgie

G. DISPLAY

1. XD-1 Status

Various character-legibility tests are being carried out. Tests currently being conducted are concerned with the effect of ambient lighting conditions and phosphor types on the legibility of characters. Subsequent tests will be conducted to determine how often a console must be adjusted in order to maintain a given legibility. A third series of tests will determine the lowest repetition rate at which a cathode-ray tube can be operated without noticeable flicker; it is hoped to eventually obtain flicker-free displays.

The magnetic-deflection system in the Charactron is presenting a problem of adjustment. Four controls are now necessary to compensate for various time constants within the deflection yoke. A new yoke, developed by Stromberg-Carlson, has been tested and appears to be superior to the one presently in use. Tests indicate that, except for a simple damping control, no additional adjustments are necessary. Further tests will be tried in the present XD-1 consoles to observe the yoke under actual operating conditions.

2. Development

a. Remote Display Consoles

A proposal is being made for the design of a remote-display console. This console will accept present ground-to-ground messages from the output of XD-1 and will display up to 63 tracks, or information messages. To simplify the circuitry, the present vectors of the track message will be replaced with a direction symbol and four characters. Preliminary design has already been started with a receiver to convert the input dipulses to "standard" pulses which will probably be between 1.0 and 5.0 μsec in length.

b. Radar Frequency Modulator

A radar frequency modulator has been designed and built for Group 48 to be used in some antijamming experiments. The modulator consists essentially of a highly stable, digital-to-analog decoder with enough associated logic circuitry to produce frequency variations, increasing in a step-wise fashion, from a minimum to a maximum value. Up to 256 steps are available, and the frequency variations can be obtained in either a sequential or completely random manner.

c. Analog Line-Driver

The production models of the analog-line-driver exhibit a rise time close to the maximum allowable; a few do not meet the specifications. Tests are under way to determine what changes are possible to improve this rise time.

R. H. Gould W. F. Santelmann
J. Kriensky H. E. Zieman

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7. Fadiman, J.R., "TX-0 Circuitry," MIT Lincoln Laboratory Report, 6M-4571 (to be published).

ESS SHAKEDOWN TESTING - WWI, MTC OPERATION

GROUP 64

Rich, E.S., Leader

Allen, D.F.
Callahan, T.R.
Decof, D.
Gates, E.K.
Glover, E.B.
Grandy, C.C.
Healy, L.D.
Holmes, L.L.
Hughes, A.D.
Lin, C.S.
Morrison, D.A.
Norcott, L.H.
Ockene, N.J.
Ogden, W.
Pughe, E.W., Jr.
Small, C.E.
Stockebrand, T.C.
Ziegler, H.L.

IV. ESS SHAKEDOWN TESTING – WWI, MTC OPERATION
GROUP 64

A. SUMMARY

The general plan for system shakedown testing of the Experimental SAGE Subsector (ESS) has been expanded to provide more details on

(1) operator requirements
(2) operating procedures at sites external to the direction center
(3) data reduction
(4) photographic recording
(5) test specifications
(6) test schedules.

The memorandums covering these areas of test planning supplement the General Test Plan, 6M-4325 (draft), and have been published for review and comment.

Reliability of the Memory Test Computer is being improved for the support of ESS and CCS (Cape Cod System) tests. The magnetic-tape system is being used full time but efforts to improve its operation continue. Specifications have been written for the purchase of two new power supplies with larger capacities than those now used. A closed-circuit TV loop is being investigated as a possible computer input.

WWI will be expanded as part of the large-scale increase in the Cape Cod System. WWI core memory will be increased from 2048 to 6144 registers. A semiautomatic height-finder request facility and equipment for accepting LRI data from Bath, Maine, will be added. Some consoles in the Cape Cod direction center will be relocated to accommodate the additional equipment. The work is expected to be completed about mid-November and, to date, is on schedule.

E.S. Rich

B. ESS PLANNING

System shakedown testing of the Experimental SAGE Subsector (ESS) will follow the individual testing of the program and equipment of the ESS and will be carried out in a system environment comprising equipment, computer programs, and AF operators. Tests will be designed to produce an operational subsector in which evaluation testing can be started by Group 22; the general objectives are to:

(1) Verify that the system operates according to specifications
(2) Diagnose causes of malfunctions in the system so that they may be corrected.

The ESS Shakedown Planning Section is responsible for formulating general plans for the system shakedown period and for designing and carrying out the specific tests that will be conducted when the major parts (including equipment, computer program, and AF operators) are combined in a system environment. The tests will require the support of many other groups. Following completion of the first draft of the General Test Plan, 6M-4325,[1] the work of the section

during this quarter has been devoted to detailed planning in specific areas to augment the General Test Plan.

The memorandums described in the following paragraphs indicate the subjects studied during the quarter. In some cases, schedules have not been adjusted to correspond with the new dates for completion of the direction center computer program.

1. Schedule for System-Testing ESS

A schedule, (6M-4223[2]) prepared in cooperation with Group 22, has been proposed for a 28-week period of ESS system tests.

2. Operator Requirements

The proficiency required of Air Force operators during ESS shakedown testing exercises is specified in 6M-4088[3] to aid those responsible for operator training. Operators at external sites are covered in Supplement 1.

The Air Force and Army manpower required to carry out a 28-week period of testing (ref. 6M-4223) is outlined in 6M-4327[4].

3. Operating Procedures

A preliminary statement of the working agreements and standing operating procedures required for sites external to the direction center has been made in 6M-4071[5]. Handbooks for operation of external sites such as AAOC's, manual air defense direction centers, CAA (AMIS), LRI (radar operators, radar mappers, and height-finder operators), and airbases, are being written jointly with Group 23.

4. Data Reduction

Test data will be recorded on magnetic tape throughout ESS shakedown exercises. Recorded data will be used to verify system operation and to aid in diagnosing difficulties. The data reduction requirements are described in 6M-4203[6] and Supplement 1, and are expected to be accomplished by a data-reduction program that is being written for the Memory Test Computer.

5. Photographic Recording

The minimum automatic and manual photographic recording in the direction center, required for certain categories of data during ESS shakedown, is specified in 6M-4354[7] and Supplement 1.

6. Simulated Problems

ESS shakedown testing will require 22 types of simulated problems over a period of six months, based on the schedule given in 6M-4223[2]. The design of these problems is detailed in 6M-4278[8] and consists mainly of punched-card inputs and scripts (outlines of the tests to guide operators and members of test teams). The weekly requirements for simulated problems to be used during ESS shakedown exercises are given in 6M-4280-1[9].

7. Computer Programs

The DCA computer program is being written and adapted to ESS by Group 67. That part of the DCA program that will have been assembled and adapted by 1 December, will be used to

begin ESS shakedown tests. The first part to become available includes the computer programs for radar inputs, manual track detection and initiation, automatic tracking, track data simulation, and recording. A preliminary outline of "packages" required for ESS shakedown was given in 6M-4408[10].

8. "Successful" Interception

A definition for the term "successful" interception for use in documents relating to ESS and SAGE System testing has been proposed in 6M-4545[11].

9. Manual Subsystems

A general plan has been drafted (6M-4405[12]) for testing the agencies of the ESS environment which supply manual-input information (flight plans, etc.) to ESS, and which receive information (e.g., scramble orders) from the direction center. This testing does not require use of computer time.

10. Raydist

A method for operating XD-1 with the Raydist system of navigation and tracking has been proposed in 6M-4245[13]. Raydist can be used for radar calibration and tracking accuracy tests in ESS; 6M-4245 modifies previous proposals primarily by changing the content of the teletype message and the method of sending timing pulses to the Raydist equipment.

C. C. Grandy
W. Ogden

C. MEMORY TEST COMPUTER

As expected, installation of the completely new central control system, and the magnetic tape equipment has necessitated several months of cleanup work to eliminate weaknesses and prove preventive maintenance equipment and procedures.

Marginal checking and other special testing techniques are being reviewed. More rigid testing than that presently performed on diodes is being considered; a circuit has been devised to test dynamic characteristics, pulse drop, and reverse recovery. The goal is a tester that is small, portable, and that will predict diode behavior in actual computer circuitry.

An experimental high-speed, magnetic-tape drive has been developed and is nearly ready for performance tests. The drive will be used as an input device for the TX-0 or TX-2 computer (See Section III, p.41).

A closed-circuit TV loop is being studied as a possible input device for digital computers. The camera would scan a typewritten, coded program and convert it to binary information to be fed directly into the computer. No tapes or cards would be necessary.

1. Power Supplies

A study of MTC power supplies was completed and results reported in 6M-4351[14]. Specifications are being written for the purchase of two new, 50-amp, thyratron-controlled, power supplies to be used in place of the present −150 and +150 volt supplies. The series regulators used on the old −150 and +150 volt supplies can be used to increase the capacity of the +250 and −300 volt supplies. These changes will relieve present overloads and provide some spare capacity for future needs.

2. Magnetic Tape System

The magnetic tape system (installed to provide tape units in MTC that will be compatible with XD-1 and with tape-to-card and tape-to-printer equipment) is in use full time, although still in the shakedown phase. Considerable time has been spent in research to do two things: (1) improve present operation by temporary methods, and (2) study design changes for long-range improvements. Study to date has been concerned with the dropping and picking up of bits as a function of gain in the read amplifiers. If the gain is too high, the noise exceeds the clip level and causes unwanted bits to be introduced. With the gain level too low, wanted signals are lost. Many problems were encountered while making these tests: spliced tapes produced intermittent errors; warped reels damaged edges of several tapes and caused errors in the outside tracks; mechanical problems associated with loading and unloading tapes give trouble.

H. L. Ziegler	D. Decof	N. J. Ockene
E. K. Gates	E. B. Glover	C. E. Small
T. R. Callahan	A. D. Hughes	T. C. Stockebrand

D. CAPE COD ENGINEERING

1. WWI Expansion

Plans have been approved for expanding WWI to make it a more useful tool for experimentation and evaluation of air defense functions in the Cape Cod System. The general plan for expansion of the Cape Cod System was formulated by Group 22 and includes a major revision of the computer master program to be done by Group 22.

The equipment changes to be performed by the Cape Cod Engineering Section include the following:

a. Long-Range Radar Input (LRI) from Bath, Maine

Four hundred and fifty (450) plug-in units will be added to make WWI capable of accepting data transmitted from the AN/FST-2 at Bath, Maine. The proposed unit will accept a maximum phone-line transmission rate of 300 messages over each of two phone lines during each 6-second computer-program subframe. The time of arrival of each message will be stored on the input drum.

b. Semiautomatic Height Finder Request Equipment

Existing WWI crosstelling equipment will be modified to transmit program-generated height requests to Bath and South Truro. The modification will be planned so that the crosstelling facility can be easily restored. The new system will accept a 5-word height request from the computer, and will interleave the words while using about 250 microseconds of computer time. Fifty additional plug-in units will be required.

c. Core Memory

The addition of 4096 registers of core memory to the existing 2048 will give programmers the use of a total of 6144 registers: these registers are arranged to form six fields each, composed of 1024 registers. A single computer instruction will permit the programmer to assign

any two of the six fields to an operational status. The new instruction will provide the following optional features:

(1) subprogramming

(2) change in the status of 2, 3 or 4 fields

(3) assignment of any field to operate with the computer as registers 1 to 1024, or 1025 to 2048.

Present computer programs will not be affected by the alteration.

d. Other Changes

The proposed change of the interlace of the magnetic drum is an attempt to reduce the block transfer time. Logic design problems are being investigated.

Changes affecting the CCDC call for relocation of the TBS facilities, improvement of equipment-generated character displays, installation of equipment for assisting CCS programmers in creating expanded displays, installation of a new console for the Recovery Officer and integration of ESS radio ground-to-air communication system.

By the end of August, schedules established for these changes were being realized. The FGD input facility for Bath, Maine and the semiautomatic height-finder request equipment changes were essentially complete and in use on a regularly scheduled basis.

The core memory expansion is on schedule; logic design for the display changes have been completed; investigation of the reduction of the drum-core memory block-transfer time is continuing.

2. WWI Computer Operation

A summary of WWI operation and reliability for this quarter, measured over 2-week periods, is given below:

	Total
Scheduled Computer Hours	2572.2
Interrupting Incidents*	114
Hours Lost	32.9
Per cent Good Time	98.8
Mean Time Between Failures (in hours)	22.3

L. L. Holmes
C. S. Lin
D. F. Allen
L. D. Healy
D. A. Morrison
L. H. Norcott
E. W. Pughe, Jr.

*The third week in August was a high point for computer operation – there were no interrupting incidents throughout the entire week.

GROUP 64

LIST OF REFERENCES

Ref. #	6M #	Title	Author(s)	Date
1.	6M-4325	General Test Plan for ESS System Shakedown	M.J. DiCarlo-Cottone	23 May 56
2.	6M-4223	Schedule for Experimental Subsector System Testing by Group 64 and Group 62	C.C. Grandy F.E. Heart W.C. Johnson	14 May 56
3.	6M-4088	Specification for Air Force Operator Proficiency Required During ESS Shakedown, Revision and Verification Exercises	C.C. Grandy T.R. Callahan	5 Jan 56
4.	6M-4327	Air Force and Army Operator Requirements for Experimental Subsector System Testing	J.D. Coyne	4 June 56
5.	6M-4071	Requirements for Standing Operating Procedures for External Sites in the Experimental SAGE Subsector (ESS)	A.G. Thomas M.J. DiCarlo-Cottone	23 Mar. 56
6.	6M-4203	Initial Data Reduction Requirements for ESS Shakedown Exercises	M.J. Clark J.R. Slagle	27 Feb. 56
7.	6M-4354	ESS Shakedown Testing Requirements for Photographic Recording	R.J. Watters	25 May 56
8.	6M-4278	ESS Shakedown Simulated Problem Design	J.D. Coyne R.F. Lawrence	3 May 56
9.	6M-4280-1	Weekly Simulated Problem Requirements for ESS Shakedown Exercises	J.D. Coyne	4 June 56
10.	6M-4408	Program Requirements for ESS Combined Program-Equipment Testing and System Shakedown Testing	M.J. DiCarlo-Cottone W.C. Johnson	24 July 56
11.	6M-4545	System Test Requirements for a Successful Interception	R.J. Watters	20 Aug. 56
12.	6M-4405	General Test Plan for ESS Shakedown Manual Subsystem Testing	M.H. Cannell	30 Aug. 56
13.	6M-4245	Details of a Proposed Method for Operating XD-1 with Raydist	R.D. Buzzard	6 Apr. 56
14.	6M-4351	Power Requirements in MTC	N.J. Ockene	4 June 56

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VACUUM TUBES

GROUP 65

Youtz, P., Leader

Clough, T.F.
Palermo, J.S.
Tandy, P.C.
Twicken, S.

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V. VACUUM TUBES
GROUP 65

A. SUMMARY

Stromberg-Carlson produced 209 acceptable Charactrons this quarter at a production efficiency of 76 per cent. This was greater than the demand at Hazeltine. Life tests on early production Charactrons were continued at Stromberg-Carlson and MIT. Considerable operational history of the Charactrons, produced prior to the fall of 1955, has been obtained from the display consoles in which seventy Charactrons had accumulated an average of 2067.2 hours as of 21 August 1956. The chief cause for failures in all of the tubes in the life-test programs continues to be low cathode emission.

Several different processing specifications have yielded bariated-nickel cathodes giving 4000-5000 hours of operation. Although there have been variations within groups, a sufficient number of successful cathodes have been processed to warrant continued development of final processing specifications.

Seventeen early production Typotrons on the MIT life rack have accumulated an average life of 7329.4 hours on 31 August 1956. Ninety-three Typotrons in the display consoles have accumulated an average of 2642.5 hours.

General Electric has submitted to Wright Field a proposed MIL specification for the low-power twin triode 6414. They have been experiencing some production difficulties with microphonics which might be associated with their P50 alloy cathode sleeve. Raytheon has started full-scale production of this tube as second source. Their first production lots lacked uniformity and did not show good centering of tube characteristics.

Sylvania has terminated the pilot production of the dual-control gate pentode, type 6888, and turned over the production to their Brookville plant. Bendix is producing the 6888 as second source but experiencing high shrinkage in their first production lots.

The IBM-sponsored development program at Tung-Sol failed to yield an improved version of the 5998. Tung-Sol will continue the program with their own funds. Both Tung-Sol and Chatham are producing the 5998 for the AN/FSQ-7.

P. Youtz

B. DISPLAY

1. Charactron

The objective of the Group 65 Charactron program is to evaluate and estimate the factors that will affect the life and performance of the 19-inch cathode-ray tube meeting the AN/FSQ-7 situation display requirements.

a. Life-Test Program

The production of acceptable Charactron tubes at Stromberg-Carlson has been greater than the demand at Hazeltine Electronics Corporation. Stromberg-Carlson, operating at a production efficiency of 76 per cent, cut back its production to 209 acceptable tubes. Even at the reduced

rate, tubes were stockpiled at the end of the quarter. Production efficiency has been improved by reducing the number of failures caused by electrical leakage and poor screen quality.

Stromberg-Carlson in San Diego, under contract with IBM, had activated in December 1955 a 12-position, life-test rack with production Charactrons made during the fall of 1955. At the end of the quarter there had been six failures in that program:

Number of Tubes	Hours of Life	Reason for Failure
1	4305	low cathode emission
1	3305	low cathode emission
1	2000	low cathode emission
1	586	excess leakage
1	505	excess leakage
1	322	cathode-grid leakage

The cumulative history of the Charactrons on the Stromberg-Carlson life-test rack on 20 August 1956 was as follows:

Number of Tubes	Hours of Life
6	4150
1	3685
1	3000
1	1500

Charactrons built by Stromberg-Carlson prior to the fall of 1955 have been on the MIT life-test rack. There were two failures during this quarter:

Number of Tubes	Hours of Life	Reason for Failure
1	4925	low cathode emission
1	2466	low cathode emission

The six tubes remaining on the MIT life-test rack have been operated for an average of 4873 hours:

Number of Tubes	Hours of Life
1	5910
1	5860
4	2850

Six similar Charactrons made at MIT have produced one failure for low cathode at 4155 hours:

Number of Tubes	Hours of Life
2	13,100
1	12,000
2	4,250
1	2,600*

*Bariated-nickel cathode.

The display consoles in XD-1 have been providing an excellent operational history of the Charactrons produced before the fall of 1955. These tubes have accumulated an average of 2067.2 hours distributed as follows:

Number of Tubes	Hours of Life
2	501-1000
4	1001-1500
6	1501-2000
12	2001-2500
14	2501-3000
14	3001-3500
13	3501-4000
3	4001-4500
1	4501-5000
1	6018

Two failures occurred during this quarter:

Number of Tubes	Hours of Life	Reason for Failure
1	3663	low cathode emission
1	1944	broken base

Hazeltine has two tubes on their 12-position life-test rack recently received from Stromberg-Carlson. At the end of the quarter they were operating the rack only nine hours a day and were investigating some equipment and test procedure difficulties. They expect to have it operating next quarter with a full complement of tubes from current production.

b. Oxide-Cathode Studies

The factors affecting cathode life in Charactron and Typotron operation are being studied. A series of tubes representing five categories of cathode activation schedules and cathode materials was processed and put on life test. Thirty-nine tubes have been put on the life-test rack; the 22 failures to date had the following history:

Number of Tubes	Average Life in Hours	Reason for Failure
12	1952	grid emission
6	1345	leakage
3	1127	low beam current
1	2128	poor beam uniformity

Seventeen tubes have accumulated an average life of 3978 hours. These life tests indicate that some of the processing techniques and cathode materials for oxide-coated cathodes are not compatible for long-life tubes. A more complete analysis will be made later.

c. Bariated-Nickel Cathodes

Eleven bariated-nickel cathode tubes were processed this quarter. In addition an evaluation program of the 59 tubes on life test which includes one large 19-inch Charactron was continued.

The tubes on life have accumulated between 2000 and 5000 hours and some of them now fail the cathode emission test and exhibit emission that is significantly non-uniform. There is no noticeable difference in this respect between the titanium and the zirconium hydride activated cathodes. Large 19-inch Charactrons will be made to test the actual degradation of character quality that can be associated with poor emission uniformity. The one 19-inch Charactron with a bariated-nickel cathode has 2600 hours of life and has shown no degradation of quality, brightness, and uniformity. Cathode-grid leakage appears to be a more frequent cause of failure than low grid-emission. This leakage is most prevalent when the tube heater is on, although, in the form of grid emission, it can also be present when the tube is cold. The following are possible means of correcting this trouble:

(1) Titanium gettering

(2) Increasing the cathode grid spacing (grid cutoff voltages are unduly high for the bariated-nickel cathode)

There have been some reports from other research laboratories that heated titanium inside a vacuum tube acts as a practical getter. Titanium also has been found to inhibit emission. Therefore, it would appear to be suitable as a grid material for inhibiting grid emission, but unsuitable as a cathode base material. The tubes on life having the titanium getters have shown some improvement over those without titanium. Therefore, G1 aperture disks of titanium have been fabricated to investigate whether they will inhibit the grid-emission effect. This investigation should be very worthwhile as the cathode grid leakage is the greatest source of difficulty in the sprayed-oxide cathode test tubes. Five bariated-nickel tubes were unsuccessfully subjected to a reactivation schedule after they failed the cathode grid-emission specification on life. A few of the tubes increased in grid-cathode leakage.

Work will continue to develop final process specifications for bariated-nickel cathodes. Uniform cathode emission has been a problem in the cathode study tubes. Although the one 19-inch Charactron with a bariated-nickel cathode has shown uniform emission, more operational Charactrons with bariated-nickel cathodes will be processed to determine the acceptability of the present quality.

d. Electron-Optics Studies

Several tubes were designed and processed to improve the brightness of the display by increasing the current density at the screen. These tubes were made from 19-inch, round, color TV bulbs obtained from Corning Glass Works. The accelerator screens were made from Colortron aperture masks obtained from CBS-Hytron. Noticeably better persistence than that of the present Charactrons was obtained in these tubes by applying up to 15 kv between the accelerator screen and the aluminized phosphor. These tubes were sent to Groups 38 and 63 for further evaluation.

2. Typotron

The objective of the Typotron program is to assure that AN/FSQ-7 will be supplied with digital-display storage tubes of sufficient long-term reliability. Fifty-five Hughes Typotrons,

from the first research tubes through the early production tubes, have been tested and evaluated by Lincoln Laboratory. Thirty-five of these tubes were put on the Group 65 life test. The early developmental tubes exhibited certain structural weaknesses that were corrected in the production tubes. The early production tubes had low resistance paths between certain of the electrodes. This was corrected in later production lots. Eighteen production tubes have been on life test for over one year. The only complete failure was due to a life-test equipment arc-over. These tubes have been tested periodically to the IBM purchase acceptance test specifications and eight tubes continued to meet all of them. These eight tubes have accumulated the following number of hours on the life rack:

Number of Tubes	Number of Hours
3	5170
2	5250
2	11042
1	11768

It is possible for a tube not to pass acceptance test specifications and still be an operable and useful tube. At the end of the quarter, all 17 of the tubes were still operable and could have been used in display consoles. No end-of-life specification has been written. Tubes have been kept on life racks and display consoles as long as they performed without complaints from the operating personnel. The operating history of the 17 tubes is as follows:

Number of Tubes	Number of Hours
6	5170
4	5250
2	11042
5	11768

No other organization has yet activated Typotron life-test racks. Hughes has a life-test rack which will be used for the 500 to 1000 hour life tests to monitor production changes in the Typotron. Hazeltine has under construction a life-test rack for the longer-term testing of sample production lots.

Later lots of production tubes have been given some operational life in XD-1, XD-2, and the display consoles in the IBM test cell. Three tubes were rejected from the display consoles this quarter.

Number of Tubes	Number of Hours	Reason for Replacement
1	1018	gassy
1	1400	gassy
1	2660	gassy

It is significant that none of the 35 Typotrons that were in the MIT life racks failed because they were gassy while over 50 per cent of the Typotrons rejected from consoles the previous quarters have been gassy. IBM, Hughes, Hazeltine, and MIT agreed that all of the Typotrons that have

failed in display consoles should be retested, dissected, and analyzed to correlate stated causes of failure with observations of the dissected components. A detailed procedure has been designed for this analysis and dissection program. A two-day program in which all interested parties will participate is scheduled for next quarter.

As of 21 August the 93 Typotrons in the display consoles had accumulated an average life of 2642.5 hours distributed as follows:

Number of Tubes	Number of Hours
3	501-1000
8	1001-1500
8	1501-2000
21	2001-2500
24	2501-3000
17	3001-3500
8	3501-4000
2	4001-4500
1	5092
1	6363

P. Youtz

C. RECEIVER TUBE RESEARCH AND ENGINEERING

1. Low-Power Twin Triode (Type 0528/6414)

a. General Electric Company

A proposed MIL specification has been submitted by General Electric to Wright Field for consideration. There are some rather basic differences between this proposal and the conventional MIL specification; these differences attempt to emphasize the factors which are most important in the operation of the AN/FSQ-7. Specifically, they are concerned with intermittent shorts, length of life test, and number of permissible inoperatives on life test.

One point remains for future inclusion in the specification after extensive investigation: We are interested in controlling the rate of deterioration on a per-tube basis, rather than merely specifying a minimum for an entire lot of tubes after life test. GE is to investigate the present rather wide fluctuations in plate current during 1000-hour life tests (increases as well as decreases), as well as the comparative control afforded by maximum limits on the change in transconductance with filament voltage. This is a fairly long-range investigation because 1000 hours of test data are needed for each evaluation.

For some time there have been production difficulties with microphonics. This is not an especially serious problem, from a systems point of view, but is indicative of something having gone awry. It is possible that this difficulty is tied up in the use of P50-alloy cathode sleeves which are softer than the 220-alloy previously used. GE is also investigating this problem.

b. Raytheon Manufacturing Company

Raytheon has acquired all necessary parts and has moved into full production of the 6414. Their early production tubes exhibit nonuniformities and point up areas of potential difficulties. The characteristics are not completely centered and will require some attention. Separate grid-making facilities for this project are being set up; in the meantime, however, grids are being used over whose manufacture complete control cannot be exercised.

Cathode alloy approval tests have been successfully completed at 2000 hours with no indication of cathode interface impedance or grid emission. Type A-31 tungsten-nickel alloy, specially selected for low silicon content, is being used.

Raytheon's rather extensive facilities for X-raying completed mounts and tubes are being used to control weld quality, electrode positioning, etc.

The first lot of tubes for AN/FSQ-7 has been shipped to IBM and evaluated.

2. Dual-Control Gate Pentode (Type SR-1782A/6888)

a. Sylvania Electric Products, Inc.

All production of this tube type at Emporium has been transferred to the Brookville, Pa., plant under the over-all engineering responsibility of Emporium, where the tube was originally conceived.

With the cut-back in IBM's schedule and the attendant cut-back in Sylvania's schedule, the Brookville operation has an opportunity to concentrate on product improvement. Some samples have been made of a small design modification intended to yield a higher positive-grid plate current. Although these samples are not yet as high in plate current as desired, indications are that the objective is close to realization. Sylvania-IBM-MIT conferences have been held to formulate the detailed design of additional samples to indicate whether we have passed the point of diminishing returns in efforts to increase the plate current.

Since the Burroughs AN/FST-2 equipment also use the type 6888, Group 65 has consulted with Burroughs regarding the effects of any increase in positive-grid plate current on FST-2 circuitry. There is only one circuit in which the effect of such an increase cannot be analytically determined; samples will have to be tried in these sockets to get the information.

Difficulties during tests at Kingston, raised the question of the adequacy of the 6888 in some timing circuits. A detailed analysis of the problem by Group 65 has determined that the specification requirement of plate current at +10 volts drive could be met by two different design geometries which did not yield similar plate current at +25 volts drive. Steps are now being taken to add to the specification a control on plate current at +25 volts drive. It is felt that two such plate-current controls in the specification will adequately cover all AN/FSQ-7 circuit requirements and, in addition, will make any appreciable tube design variations quite difficult.

b. Bendix Aviation Corporation, Red Bank Division

Bendix has made several deliveries of 6888's to IBM. The initial quality of these tubes is acceptable, but Bendix is experiencing more than normal shrinkage in meeting the specification.

The major source of difficulty is high screen-grid current. This can be alleviated by one or both of two actions: better assembly techniques and a small change in electrode dimensions. Slightly misaligned screen grids can be eliminated only by more experience on the part of the operators and better control of manufacturing procedures. Under the test condition, the screen current is a function of the relative position of the suppressor grid between anode and screen and a suitable change in suppressor grid diameter was suggested to Bendix. These difficulties do not represent a potential source of system unreliability, but they lead to a manufacturing shrinkage level high enough to generate empirical changes in dimensions and processing in an effort to reduce the shrinkage level. The long-term effects of many such changes cannot be ascertained beforehand and introduce additional risk.

3. High-Power Twin-Triode (DT-438)

a. Tung-Sol Electric Company

The original IBM contract with Tung-Sol for the development of the DT-438, a 5998 with increased reliability, expired on 15 July without the achievement of a tube in full production or a final specification. Tung-Sol has agreed to carry the program through to completion under its own funds.

An intensive effort to clean up manufacturing techniques and parts handling, coupled with the recommendations of the joint IBM-MIT committee have resulted in a condition of stability such that an evaluation of the tube can be made that is unclouded by various production disasters. A detailed investigation by Tung-Sol of the resonance and amplitude of vibration of grid laterals has led them to the belief that the grid construction formerly used is superior to that now in use from the point of view of vibration under impact. Accordingly, the former design will be used. In addition, Tung-Sol feels that the reliability desired is not attainable in the present structure where grid-cathode and grid-anode spacings are 0.006 inch. Sample tubes with greater electrode spacings in several different designs are being made up in an effort to find one that will duplicate the characteristics of the prototype 5998 and be less prone to intermittent shorts.

b. Chatham Electronics

For some time, Chatham has been providing 5998's for use in AN/FSQ-7 systems until the DT-438 will have become available in quantity. These tubes have been fairly satisfactory, although the plate current has been somewhat low. This is a manufacturing problem which can probably be corrected by minor adjustments of electrode spacings.

It had been planned that IBM would give Chatham an order for DT-438's, so that Chatham could become a second source for IBM. Although this would be an ideal situation, there is some question as to its practicability. Although the 5998/DT-438 is an important tube type and is used in a critical portion of the system, the quantity of tubes involved is relatively small. Dividing this relatively small quantity (about 4000 per system) between two suppliers introduces problems of manufacturing continuity at efficient levels and major problems in economics at inefficient levels. The Air Force is holding this order in abeyance pending a final decision.

4. Research

A considerable mass of individual vacuum-tube life data in the form of punched cards has been accumulated over the last eight years in the operation of the Whirlwind I computer. The cards themselves hold information regarding initial characteristics, conditions of operation, time to failure, etc. Fairly important data on the rate of deterioration of the oxide-coated cathode under conservative operation could be obtained if the state of the cathode could be accurately determined.

Many methods for evaluating oxide-coated cathodes are in use. For the most part, they involve empirical techniques primarily used for comparison of cathodes. Considerable work has been done in the last quarter toward determining whether direct measurements yielding a calculation of the donor density within the cathode coating are feasible. Information as to the rate of decrease of donor density would be of considerable value.

Calculation of the donor density derives from measurements of the change in Fermi Level with temperature which can be determined from changes in the zero-field voltage with temperature. In a practical tube, accurate measurements of cathode temperature with an optical pyrometer are not feasible. Emitting surfaces show considerable variations in temperature and the cathode itself is frequently hidden by other tube elements surrounding it. An attempt is being made to determine the cathode temperature from the slope of the retarding potential characteristic at collector (grid #1) currents of 10^{-9} ampere and lower. For accurate measurements there must be no curvature of the characteristic over several orders of magnitude above 10^{-11} ampere. The requirement that the zero-field voltage be measured to an accuracy of a few millivolts requires that the measurements be made at low cathode temperatures (about 500-600°K). On new tubes, these requirements pose no major problem. On some deteriorated tubes, however, it has been found that the retarding potential characteristic deviates markedly from a straight line at about 10^{-10} or 10^{-9} ampere because the more inactive portions of the cathode are the first to become temperature-limited. This curvature of the characteristic makes an accurate determination of temperature impossible. This is the point which the investigation has reached; it is being continued.

S. Twicken

SAGE DC AND CC SITES

GROUP 66

Morriss, B.E., Leader

Alperin, N.
Ayer, W.H.
Carson, J.J.
Gray, P.J.
Johnson, F.B.
Lundberg, E.D.
Manning, F.F.
Mayer, R.P.
McVicar, K.E.
Murphy, P.J.
Roberts, A.J.
Rundquist, H.I.
Shorey, R.A.
Shortell, A.
Smiley, E.L.
Thompson, S.L.
Werlin, A.M.

VI. SAGE DC AND CC SITES
GROUP 66

A. SUMMARY

The responsibility for adapting, installing, and checking out the air defense computer programs at the first three SAGE sites was assigned to Group 66 early in the quarter. In the course of making the McGuire, Stewart, and Syracuse centers operational, Group 66 will train the people necessary to make the remaining sectors and subsectors in the SAGE System operational. As a first step, a study was made of the schedules set up for the availability of the program for the active computer of a direction center (the DCA program); and a schedule of the work at the sites, together with the assumptions upon which the schedule was based, was published as 6M-4397, "SAGE On-Site Air Defense Program Checkout Schedule." The manpower that will be required to accomplish program installation was estimated on the basis of 6M-4397; approximately 30 new staff people per month will be needed until a total of 400 has been employed. The RAND Corporation has contracted to perform the program installation at the sites subsequent to the first three and has initiated an intensive recruiting campaign to hire the people required. Since these new people will be primarily inexperienced, a training program was established for them by Group 66.

Best estimates indicate that a total of ten teams, composed of about forty staff people each, will be required. Each team will be divided into three sections covering the following related but definitive activities:

(1) a. Computer operations,
b. Installation and checkout of the utility system;

(2) Installation and checkout of the air surveillance portion of the DCA computer program;

(3) Installation and checkout of the weapons direction portion of the DCA computer program.

Responsibility for the Equipment Program Services Committee (EPSCOM), which wrote computer programs for testing subsector equipment, was taken over by Bell Telephone Laboratories during the first part of the quarter. The EPSCOM organization within Group 66 was dissolved during the second week of July.

Responsibility for the Division 6 Production Coordination Office (PCO) was transferred to the Lincoln PCO in Division 2 early in the quarter. Some problems of a PCO nature remained and are being handled by one man in Group 60. The people who had been working in this activity were reassigned within Group 66.

B. E. Morriss

B. COMPUTER PROGRAM INSTALLATION AT SAGE SITES

Group 66 will adapt, install, and check out the DCA computer program at the first three SAGE centers, McGuire, Stewart, and Syracuse. The direction center at McGuire Air Force Base is the first site scheduled to become operational, and the installation of the DCA computer program at McGuire will provide on-the-job training for the RAND people who will carry on

this work throughout the SAGE System. The first step taken was establishment of a schedule of program installation based upon the best estimates of program availability, computer installations, and manpower requirements. "SAGE On-Site Air Defense Program Checkout Schedule," 6M-4397, was written and establishes this schedule giving the assumptions upon which it was based. Manpower requirements were estimated on the basis of 6M-4397 and a total of 400 new staff people at the rate of approximately 30 per month will be hired by the RAND Corporation.

Approximately 40 staff people will be assigned to each of 10 checkout teams, each of which will be divided into 3 sections covering the following related but definitive activities:

(1) a. Computer operations
b. Installation and checkout of the utility system

(2) Installation and checkout of the air surveillance portion of the DCA computer program

(3) Installation and checkout of the weapons direction portion of the DCA computer program.

Because the RAND Corporation will eventually be responsible for program installation and checkout at SAGE sites across the country and for keeping the air defense computer programs up to date, they initiated an intensive recruiting campaign to hire the people required. Since these new people will be primarily inexperienced, Group 66 established a training activity to acquaint them with the operational specifications, air defense computer programs, utility system, and program checkout activities of the SAGE System. To accomplish the program installation and checkout and the training required, the following sections were organized within Group 66:

1. Training Section

This section will acquaint the new RAND people with SAGE System operations and the DCA computer program. Special flow diagrams were designed to pictorially represent each subprogram in the DCA program in a manner which would clearly show the relationships between the parts of the program, the tables, etc., and make the program operation easier to follow and understand. The training program that has been set up is described in 6M-4428, "Group 66 Training Document: DCA Program Checkout Organization," dated 16 August 1956; and 6M-4600, "Group 66 Training Document: Dynamic Flow Diagrams for SAGE," second draft dated 24 August 1956.

2. Air Surveillance Section

This section will organize checkout teams to install and test the air surveillance package of the DCA computer program at SAGE sites.

3. Weapons Direction Section

This section will organize checkout teams to install and test the weapons direction package of the DCA computer program at SAGE sites.

4. Computer Operations Section

The people assigned to this section will take special training courses at Kingston, N.Y., to study computer operation and to install the SAGE System of utility programs in XD-2 and

AN/FSQ-7's before they are shipped to the direction centers. A few people were sent to Kingston in mid-July to:

(a) gain as much experience as possible in checkout of the utility system of programs before it is installed at a SAGE site

(b) confirm that the utility system will work in the AN/FSQ-7 machines (the system was designed using XD-1, the experimental prototype of the AN/FSQ-7)

(c) take advantage of the computer time available on AN/FSQ-7's, still in the process of assembly by IBM, for training and testing.

5. Adaptation Section

This section will make the necessary modifications to the computer programs to adapt them to the peculiarities of each SAGE site.

6. Documentation Section

This section will provide document control and a library of the information needed by the people in Group 66. This activity will include the collecting and distributing of all documents within the Group as well as control of security material.

7. Test Support Section

This section will provide liaison with Group 67 and keep the people in the field informed of program modifications and new testing methods or procedures.

Group 66 took on their new job with a total of 14 Lincoln and RAND staff members. At the end of this quarter, 18 new people had joined the Group, 9 of whom were assigned to the computer operations section and the other 9, for a brief period, to the training section. The experienced personnel within the Group worked to establish training methods and write the training documents for the new people.

N. Alperin	E. D. Lundberg	P. J. Murphy	A. Shortell
W. H. Ayer	F. F. Manning	A. J. Roberts	E. L. Smiley
J. J. Carson	R. P. Mayer	H. I. Rundquist	S. L. Thompson
P. J. Gray	K. E. McVicar	R. A. Shorey	A. M. Werlin
F. B. Johnson			

PROGRAM PRODUCTION

GROUP 67

Arnow, J.A., Leader

Arden, Marguerite
Bagley, P.R.
Bailey, D.L.
Benington, H.D.
Briscoe, H.
Burrows, J.H.
Carson, J.J.
Chandler, A.R.
Char, Beverly
Clapp, Elizabeth
Collins, L.B.
Coyne, J.D.
Ferguson, Mary
Frachtman, H.
Ginsberg, A.
Gochman, H.
Hager, L.
Hazel, Inez
Hills, A.M.
Kelley, Frances
Kirshner, H.
Latimer, D.
Lundberg, E.
Marney, G.
McEvoy, Eleanor
Newhall, H.
Patton, R.L.
Rising, H.K.
Rupp, A.
Stone, Judith
Thomas, L.
Vance, P.R.
Wilson, L.D.
Zraket, C.

VII. PROGRAM PRODUCTION
GROUP 67

A. SUMMARY

To eliminate further delay in the shakedown testing activities of Group 64 as a result of the slippage in the programming schedule, reported in the previous Quarterly Progress Report, the computer program for the active computer of a SAGE direction center (the DCA program) has been broken down into two major parts: air surveillance and weapons direction. The group of programs which make up the air surveillance "package" are expected to be coded, parameter checked, assembly tested, and adapted to the Experimental SAGE Subsector (ESS) in time for Group 64's activities, which are scheduled to start about the first of December. At the end of the quarter, the coding and parameter checkout of this package was about 87 per cent complete.

Test procedures have been established, input simulation programs have been written, and the recording and processing programs for test outputs have been provided for the assembly testing of the DCA program. All 22 programs of the air surveillance package were coded, and testing had been completed on the 6 programs of the radar-inputs function.

Coding was completed for adapting the 22 programs of the air surveillance package to ESS. About 3000 registers of information are involved in the adaptation parameters.

Differences between the AN/FSQ-7 computer and its prototype, the XD-1, and the manner in which the differences will affect the computer programs have been determined; the necessary modifications to the programs are being made. The specifications required to bring the console keyboard input switches for XD-1 and AN/FSQ-7 into agreement with the latest version of the operational specifications have been issued. A check of the operational specifications against the computer program continues so that discrepancies between them may be eliminated.

J. A. Arnow, Group Leader
H. D. Benington
C. Zraket

B. DCA COMPUTER PROGRAM

The computer program for the active computer of a SAGE direction center (the DCA program) has been broken down into the two major parts, air surveillance and weapons direction, so that the group of programs which make up the air surveillance "package" can be turned over to Group 64 for ESS shakedown testing as soon as they have been assembly-tested and adapted to ESS. This breakdown will make part of the DCA program available by December, and eliminate further delay in the shakedown activities of Group 64 as a result of the slippage in the programming schedule.*

There are presently 71 computer programs (totaling 69,733 instructions, excluding tables) in the total DCA program, of which 22 make up the initial air surveillance package. This package consists of the radar-inputs, tracking, manual initiation, recording, and program-operations functions. The remaining 49 programs have not yet been precisely broken down, but will be assigned to either the air surveillance or the weapons direction package.

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*MIT Lincoln Laboratory Quarterly Progress Report, Division 6 (15 June 1956).

GROUP 67

Percentage of completion of the air surveillance (AS) package, as presently made up, and of the DCA program as a whole is as follows:

	AS Pkg.	Total DCA
Coding Specifications	99.6	98.0
Coding	98.5	92.0
Parameter Checkout	87.0	67.0
Assembly Testing	20.0	2.0
Adaptation Specifications	95.0	33.0
ESS Adaptation	90.0	32.0
Total (average)	81.7	54.0

1. Program Tests

a. Parameter Checkout

Each subprogram of the DCA program is individually tested on the XD-1 computer to insure that it satisfies its transfer function* as specified in the coding specifications. The parts of the complete system of programs that are pertinent to the program being tested are simulated. The conditions under which the parameter checkout test is made and the results obtained are carefully controlled and recorded in a set of test specifications.

The switch interpretation programs required for the air surveillance package have completed parameter checkout and have been released for assembly testing. Remaining switch interpretations programs will be checked out according to the requirements for assembly testing of subsequent packages.

The program-operation programs (startover, sequence control, program timing) also completed parameter checkout during this quarter and are ready for assembly testing with the air surveillance package. These are the programs that control the computer operations to be performed on the DCA program when it is operated as a whole system.

Design of the parameter checkout for the complete group of programs for digital display has been started. The many other parts of the system that affect digital displays make this job difficult in terms of both available manpower and the time and storage capacity of the computer.

b. Assembly Testing

When a related group of subprograms have completed parameter checkout, they are assembled and operated together under carefully controlled conditions. The test procedures have been established, input simulation programs have been written, and the recording and processing programs for the test outputs have been provided. Initial assembly testing of the program-operation group of programs was performed; the 22 programs of the air surveillance package were assembled and testing began on the radar-inputs and tracking programs of this package.

Initial assembly tests were designed so that an elementary radar-input function would be provided for assembly-testing the automatic tracking and track initiation functions. For the purposes of test, the radar-input function was defined as programs which receive and control real

*The means by which a program processes information contained in the system.

and simulated radar data and convert the data to the mathematical coordinate system of the subsector. The six programs tested of the radar-inputs function are:

KSS – ASO switch interpretation
KSR – mapping supervisors switch interpretation
KTB – TBS switch interpretation
CMT – simulated tape read
MSG – real-time data generation
TRI – radar input

At first, a small group of programs were operated with few pieces of data and later all six were operated together with near-capacity quantities of data. Final tests included the use of display-console switches and data from the LRI and GFI drums in a manner similar to what may be normally expected under real operation.

2. Adaptation

a. Subsector

Every item in the DCA program whose value is a constant and depends upon the geography, equipment, or external site of a particular subsector is an adaptation parameter. Any value that may differ from one subsector to another must be provided for in the DCA program. Design notes have been written on 51 of the total of 71 subprograms and describe each in terms of the following:

(1) information required
(2) how the program will use the information and the format and precision required
(3) how the information will be converted to the form required by the program
(4) the sources of information.

The raw data contained in the design notes were coded and cards punched for recompilation with each subprogram. Coding was completed for the adaptation of the 22 programs of the AS package to ESS, including those for the radar-inputs, automatic tracking, track initiation, and monitoring functions. The adaptation parameters involved comprise approximately 3,000 registers of information.

b. AN/FSQ-7

The DCA program has been written using the XD-1 computer, which is the prototype of the AN/FSQ-7. Because of differences between the two machines, the DCA program will have to be modified somewhat to operate with the AN/FSQ-7. The differences and the manner in which they would affect the computer programs have been determined and the necessary modifications will be made.

D. L. Bailey
H. Briscoe
J. J. Carson
A. R. Chandler
Elizabeth Clapp
L. B. Collins
J. D. Coyne
H. Frachtman
A. Ginsberg
L. Hager
Inez Hazel
Frances Kelley
H. Kirshner
D. Latimer
G. Marnie
R. L. Patton
A. Rupp
L. Thomas

GROUP 67

C. UTILITY SYSTEM

All except three of the programs in the Utility System* are in operation; the programs for storage print, library output, and tape processor are being written.

Modifications being made to the Utility System include:

(1) The compiler is being modified to accept an input tape recorded on the IBM card-to-tape converter. This will speed up the reading of cards by a factor of about 25.

(2) The octal load program is being modified to accept symbolic locations as well as octal locations.

(3) Prepunched control cards, known as "pseudo control cards" are replacing most of the manual switch actions required for control of computer operations during routine computer runs, thereby increasing speed and accuracy.**

Every utility program must pass a test to demonstrate that it is capable of performing as required by the program specifications. Specifications and card decks are being prepared for testing of the assembly compool, compiler, library merge, read-in, octal load, and card-input editor programs.

P. R. Vance	J. H. Burrows	A. M. Hills
Marguerite Arden	Beverly Char	Judith Stone
P. R. Bagley	Eleanor McEvoy	L. D. Wilson

D. PROGRAM DESIGN CONTROL

1. Program and Table Design

Most of the data storage and table designs for the DCA program were completed at the beginning of this quarter. Procedures have been developed for reporting the following information to the people who are writing and testing the DCA program.

(a) The Compool (Communication Tag Pool) contains the information required by the Lincoln Utility System for processing the symbolic item and table tags used in coding the DCA program.

(b) The Item Listing is a list of the basic descriptive information for each piece of data in the data-storage tables.

(c) The Glossary of Item, Table, and Program Tags contains the definition of each symbolic item, table, and program tag used in the DCA program.

(d) The Set/Use Listing is a list of each item in the DCA program and gives the subprograms that set and use each item.

(e) The Table Handbook summarizes the basic descriptive information for each data-storage table.

(f) The Storage Allocation Report contains the core and drum storage requirements of each DCA subprogram and a summary of the total drum storage requirements for programs and tables.

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*MIT Lincoln Laboratory Quarterly Progress Reports, Division 6 (15 March and 15 June 1956) and Bagley, P.R., "Description of Lincoln Utility System II," MIT Lincoln Laboratory Report 6M-4229-1 (16 April 1956).

**Carmichael, R.L., BTL, "Pseudo Control Cards for UCP," MIT Lincoln Laboratory Report 6M-4342 (18 May 1956) and Bagley, P.R., "Pseudo Control Cards for the Utility Systems," MIT Lincoln Laboratory Report 6M-4376-1 (9 August 1956).

The sequence parameters for the air surveillance package of the DCA program were established and written in symbolic form which will be interpreted by the assemble sequence-parameter program.

2. Equipment Coordination

All proposals to modify the computer equipment, regardless of who originates the proposal, must be coordinated with the people writing the computer programs to insure that the parts of the program already written (a) will not be affected by the change, or (b) if affected, the change can be thoroughly evaluated before it is approved. This responsibility requires close coordination with the Design Control Office of Group 62.

The people in this section are also responsible for maintaining up-to-date specifications of the connections between display consoles and the computer. At the beginning of the quarter, a set of five specifications had been issued for the console keyboard input switches for XD-1; a similar set for AN/FSQ-7 was issued during the quarter, bringing console switch connections into agreement with the latest version of the operational specifications.

Differences between the operations of the computer program and the latest pertinent operational specifications have been found because:

(a) parts of the program were based on earlier versions of the operational specifications;

(b) the programming cost of some operational features was too high;

(c) inconsistencies in the operational specifications were uncovered while writing the computer programs.

Supplements, written to cover the discrepancies, and the latest version of the operational specifications constitute the operational specifications for the computer program. At the end of the quarter, about half of the specifications had been checked against the program.

H. K. Rising
Mary Ferguson
H. Gochman
H. Newhall
E. Lundberg

ADMINISTRATION AND SERVICES

Assistant Division Heads

Dodd, S.H.
Jacobs, J.F.
Taylor, N.H.

Staff

Farr, C.W.
Parkins, T.R.

GROUP 60

Proctor, J.C., Leader

Biagiotti, R.
Brock, S.T.
Essler, G.
Falcione, A.M.
Hazel, F.P.
Heidler, G.R.
Hodgdon, H.W.
Kates, W.A.
Morley, H.B.
Morrione, C., Jr.
Smith, A.H.

VIII. ADMINISTRATION AND SERVICES
GROUP 60

A. SUMMARY

Electronic construction, mechanical design, component analyses, and model shop services are provided by Group 60 for special Division 6 jobs. Drafting, editorial, reproduction, and distribution services are also provided for Division 6 memorandums and reports. Allocation of Division space and administration of Division personnel is also the responsibility of this group.

The feasibility of single-knob control of marginal checking voltages has been demonstrated by a prototype power supply. This appears to solve the problem of accurately varying marginal checking voltages between limits of –150 volts and +150 volts with minimum chance for error. An order for three of the new designs has been placed.

The size of the Memory Test Computer input mixer plug-in unit has been greatly reduced and, at the same time, made more versatile by the design of a molded plastic package based on the use of Amphenol ribbon connectors and American Marine Products taper-pin holders. The mixer package was designed for quantity production and vendor quotations have been solicited.

J.C. Proctor

B. GENERAL ENGINEERING

1. Dos Magnetometer – Helium Dewar

A design for a helium Dewar vessel was requested by Group 63 for determining various magnetic properties of single- and multiple-crystal material. Investigation indicated that Hoffman Labs, Newark, N.J., have produced suitable vessels of this type. A preliminary design was drawn up for a Dewar vessel with the working section made of copper, which would have a maximum 1-1/8" OD, and which would be rotatable while in operation. An order was placed with Hoffman about 15 June.

The bearing mount developed for the Dewar required a sleeve bearing to allow a height adjustment of about 1 inch to the coil mount in the magnetometer. Because conventional materials do not perform well at liquid helium temperatures, the sleeve bearing was made of a graphite and teflon composition (Rulon) with a nylon, multiball, thrust bearing. The final boring of the sleeve bearing will be made when the Dewar vessel is received from the vendor.

One sample holder was designed for use with the Dewar vessel which will accommodate a Leeds-Northrup platinum resistance thermometer, a heater, and the sample of material under test. Nonparamagnetic material must be used in the working section of the Dewar and heat dissipation must be kept uniform to prevent interference with delicate measurements on test samples. The unit was ordered from a vendor and delivered at the end of the quarter.

2. Data Card for Kelvin & Hughes Camera-Projector

Analysis of Kelvin & Hughes camera-projector data taken during subsystems and shakedown tests has been simplified by incorporating identification data directly on each strip of film as

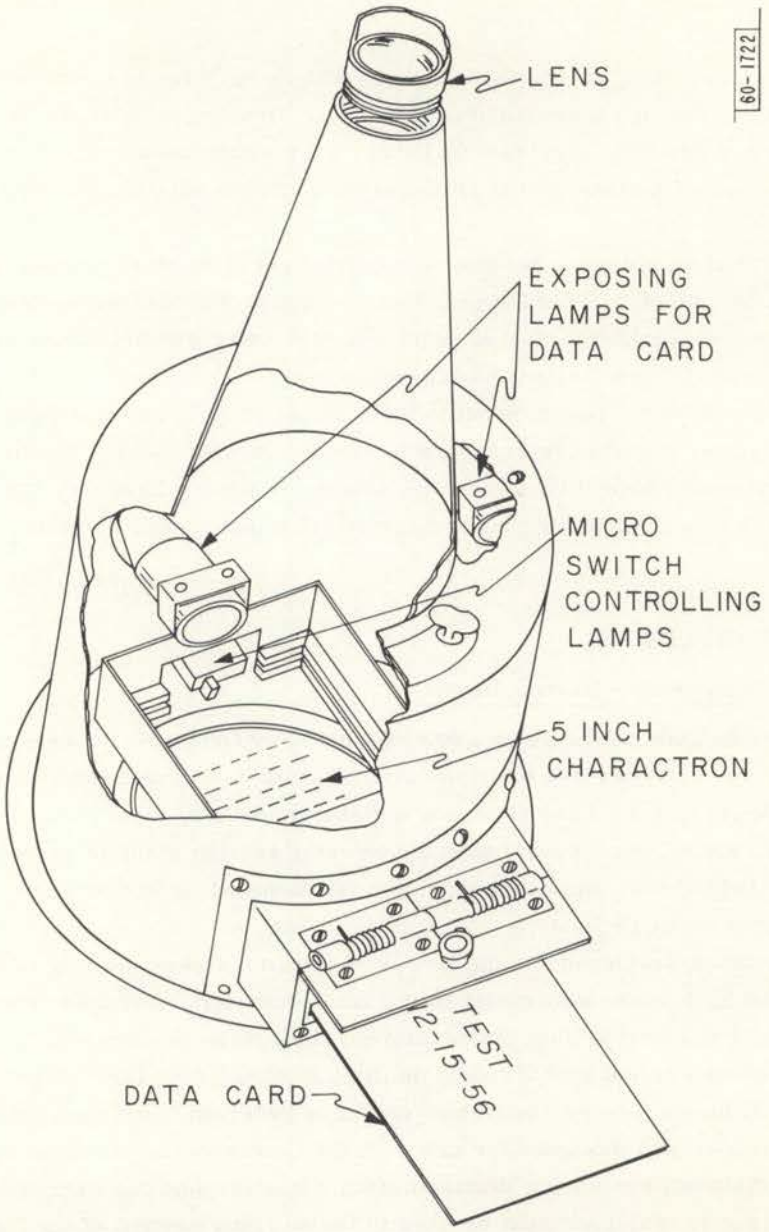


Fig. 60-1. Data card assembly.

it is exposed. A light-tight cone was designed into which the operator inserts a white vinyl card with pencil notations. The card and the Charactron data are recorded at the same time (Fig. 60-1).

3. Fire Annunciator for Building F

Based on the results of tests performed on the breadboard model under environmental conditions, the design objective of the fire annunciator system was established: A means must be provided for determining the source of an alarm within the direction center which will allow the shift chief time enough to evaluate the situation before filling the sprinkler system with water. A highly sensitive thermostat system was decided upon as the most satisfactory solution. A smoke detector design was considered, but was rejected because:

(1) The high voltage velocity experienced in the ducts would set off false alarms.

(2) Adequate protection could not be provided at a reasonable cost.

It is hoped to have the system completed and installed in the spring of 1957.

4. Core Test Handler

The prototype model* has operated very satisfactorily while testing 80-50 mil cores. However, difficulty has been experienced while testing 50-30 mil cores. The trouble seems to be that, due to the infinitesimal weight of the small cores, the other environmental properties have a proportionally larger effect than was expected. A second model has been built to study corrective measures as each malfunction presents itself. The principal areas of difficulty have been at the probe stage and the feed lines from the moving to the stationary tracks.

5. Printed Circuits for Memory Planes

Techniques for producing in quantity circuits for memory planes are still being evaluated. It is desired to achieve extremely close dimensional tolerances with the simplicity and flexibility required of production processes by using as many standard photographic techniques as possible. Major effort during the quarter has been directed toward the fabricating of planes for mounting the cores, providing surfaces that are suitable for printed-circuit processing, and developing improved techniques for producing circuitry contact negatives.

6. Marginal Checking Power Supply for TX-2

A prototype power supply was built to demonstrate the feasibility of single-knob control of marginal checking (Fig. 60-2). Designs submitted by the System Design Section of Group 63 called for the knob to rotate through 180° while driving the negative potentiometers through 360° while positive potentiometers remain at rest in zero position. Conversely, an additional 180° rotation of the control knob drives positive potentiometers through 360° while holding negative potentiometers at rest in zero position. The use of gears to engage and disengage from the negative and positive potentiometers was tried, but a gear segment, once disengaged from its mating gear, would at times slip out of position and jam or bind. A positive cam, operating a

*MIT Lincoln Laboratory Quarterly Progress Report, Section VIII., 3., Group 60 (15 June 1956).

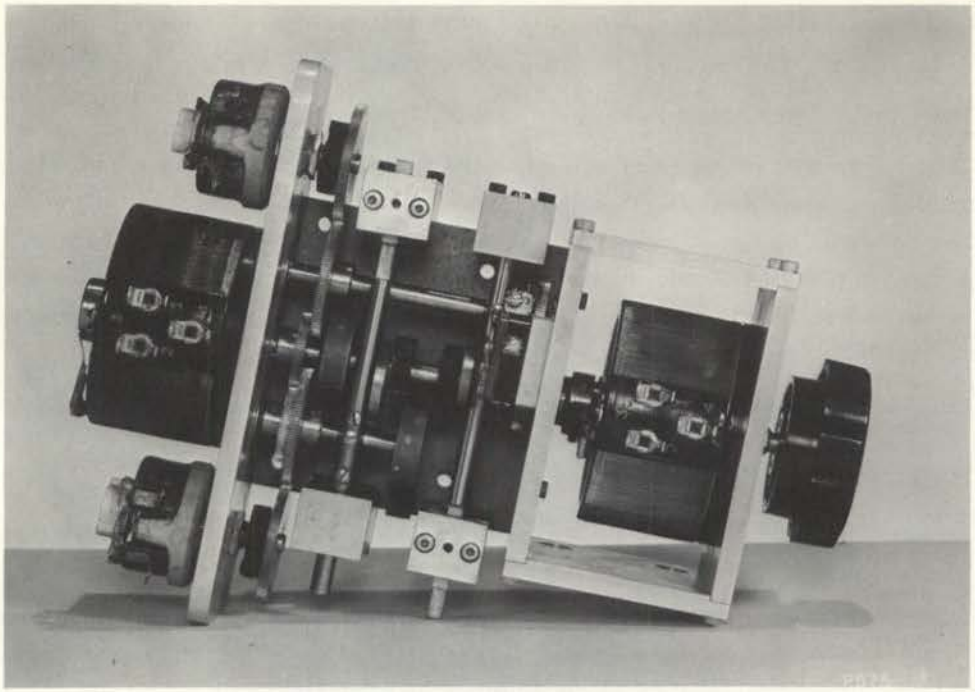
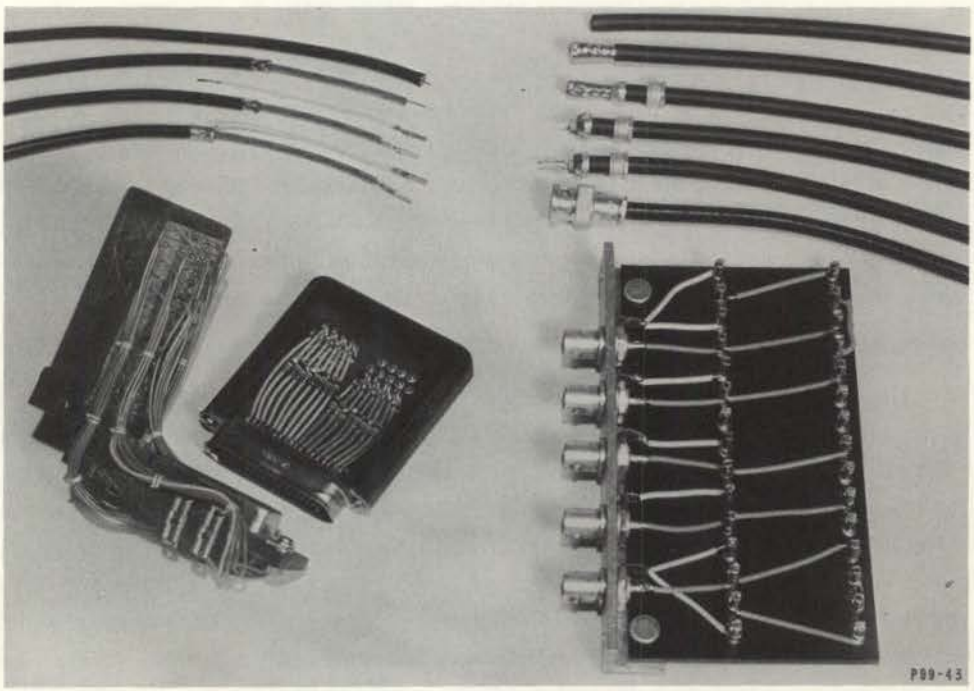


Fig. 60-2. Marginal checking power supply with single-knob control for TX-2.



(a) (b)

Fig. 60-3. Input mixer for MTC. One of the new units (a) will handle more than six times the inputs that are possible with the present unit (b).

rack and pinion, corrected the condition and replaced the sector gear system. At the end of the quarter an order for three such power supplies was submitted to vendors.

7. Input Mixer for MTC

The General Engineering Section has completed a package for a simple, compact input mixer unit designed by Group 64 around two recently developed components – Amphenol ribbon connectors and American Marine Products taper-pin holders. A molded plastic, L-shaped frame carries a panel containing 120 taper-pin holders and a jack for a 34-line ribbon connector. A separate molded plastic frame holds the mating 34-line ribbon connector plug and 4 to 8 input diode mixers (Fig. 60-3). The new units will be mounted on 2-inch centers between present plug-in unit frames. Vendors of molded plastic parts have been given drawings and have been asked to submit quotations on quantity production.

A. R. Smith G. R. Heidler
G. Essler L. B. Prentice

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